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DEPARTMENT OF THE INTERIOR—U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND MINERAL RESOURCES
OF THE
JUDITH MOUNTAINS OF MONTANA

BY

WALTER HARVEY WEED
AND
LOUIS VALENTINE PIRSSON

EXTRACT FROM THE EIGHTEENTH ANNUAL REPORT OF THE SURVEY, 1896-97
PART III—ECONOMIC GEOLOGY

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GEOLOGY AND MINERAL RESOURCES OF THE JUDITH MOUNTAINS OF MONTANA.

BY

WALTER HARVEY WEED AND LOUIS VALENTINE PIRSSON.

CONTENTS.

Page.
Prefatory remarks, by W. H. Weed 445
Chapter I. Introduction, by W. H. Weed 446
Chapter II. Topography and hydrography, by L. V. Pirsson 450
The mountains 450
Valleys and streams 452
Climate and rainfall 452
Character of streams 452
Boyd Creek 452
Burnett Creek 453
Warm Spring Creek 453
Armell Creek 454
Box Elder Creek 454
Streams on the south side of the mountains 454
Valleys 454
Forests 455
Roads 456
Chapter III. General geology, by W. H. Weed 457
Statement of problem 457
Unconformity 458
Paleozoic history 458
Cambrian time 459
Siluro-Devonian time 459
Carboniferous movement 459
Post-Carboniferous movement 460
Pre-Cretaceous movement 460
Early Cretaceous movement 461
Middle Cretaceous movement 461
Colorado time 461
Post-Cretaceous movements and mountain-building 462
Paleozoic stratified rocks 464
Cambrian rocks 465
Siluro-Devonian rocks 468
Carboniferous rocks 470
Fossils 473
Résumé 475
Mesozoic rocks 475
Jurassic rocks 476
Jura-Cretaceous section 477
Fossils 478
Lower Cretaceous rocks=Kootanie 480
Fossils 480
Upper Cretaceous rocks 482
Dakota group 482
Benton formation 482

Page.
CHAPTER IV. Descriptive geology, by L. V. Pirsson 485
  The western part of the mountains 485
    Introductory 485
      The geologic map 485
    The western foothills country 486
    Burnett Creek dome and laccolith 487
    Ruby Gulch 491
    Pyramid Peak 494
    Pyramid Gulch 495
    Upper Boyd Creek 498
        Kelly Hill 499
    Flat Mountain 500
    Ridge between Flat Mountain and Alpine Creek 501
    The Alpine laccolith 502
    New Years Creek and Valley 507
    Giltedge Creek 508
  The middle part of the mountains 510
    Upper Warm Spring Creek and Valley 510
        Phonolite-porphyry 514
    North Fork of Warm Spring Creek 514
    Bald Butte and the Warm Spring Creek dome 516
    Heads of Deer Creek 520
        Deer Creek dome 520
        East fork of Deer Creek 521
    West Armell Creek 523
    Spotted Horse Gulch 525
    Canyon of Maiden Creek 529
    Crystal Peak anticline 530
    Collar Creek and Gulch 531
    Maginnis anticlinal dome 533
    Judith Peak and Red Mountain 533
      Porphyry Peak 534
      Judith Peak 535
      Red Mountain 536
  The eastern part of the mountains 538
    East Armell Creek 538
    West Maginnis Creek 540
    Maginnis Peak intrusive 541
    East Maginnis Creek 541
    Elk Peak anticline and laccolith 542
      Elk Peak 543
      Peerless Gulch 545
    Lewis Peak 546
    Ross Pass 547
    Cone Butte Mountains 548
      Cone Butte 551
      Intruded sheets and dikes on south side 551
    Lookout Peak laccolith 552
    Black Butte 553
    Country south of the Cone Butte Mountains 556
CHAPTER V. The igneous rocks, by L. V. Pirsson 557
  Introduction 557

CHAPTER V. The igneous rocks—Continued.

Page.
- Granite family 558
  - Granite-porphyry 558
    - Megascopic appearance 558
    - Microscopic characters 559
  - Rhyolite-porphyry (quartz-porphyry) 560
    - Megascopic characters 560
    - Microscopic characters 560
- Syenite family 561
  - Syenite 561
    - Megascopic characters 561
    - Microscopic characters 561
  - Syenite-porphyries and diorite-porphyries 562
    - General discussion 562
    - Syenite-porphyry 564
    - Diorite-porphyry 565
- Phonolite family 566
  - Ægirite-syenite-porphyry 566
  - Tinguaite-porphyry 567
    - Megascopic characters 568
    - Microscopic characters 568
    - Chemical analyses 569
  - Nonporphyritic tinguaite 571
    - Description 571
    - Weathering 571
    - Tinguaite border facies 572
- General petrology 572
  - Origin of dikes and sheets 572
  - Size of grain not dependent on depth 574
- Summary 575

CHAPTER VI. Dynamic and structural geology, by L. V. Pirsson 576
  - Introductory 576
  - Position and number of Judith Mountain laccoliths 576
  - Proofs of the laccolithic character of the intrusions 578
  - Horizons invaded 578
  - Gradation between sheets and laccoliths 579
  - Forms of laccoliths 579
    - Asymmetric laccoliths 581
  - Jointing in laccoliths 582
  - Depth of laccolithic intrusion 583
  - Contact metamorphism 583
  - Origin and cause of laccoliths 584
  - The intrusive stocks 587
  - Summary 587

CHAPTER VII. Mineral resources, by W. H. Weed and L. V. Pirsson 588
- History of development 588
- The ore deposits 589
  - Character of the ores 589
  - Mode of occurrences of the ores 592
    - Ore deposits in porphyry 593
    - Ore deposits along dike contacts 593
    - Ore deposits in limestone near contact with igneous rocks 594
  - Source and deposition of the ores 594
- Future of the district 598

CHAPTER VII. Mineral resources—Continued.

Page.
- Descriptions of mining properties 599
  - Maginnis mine 599
  - P. K. mine 601
  - Spotted Horse mine 602
  - Florence mine 606
  - Pilgrim mine 606
  - Butcher Knife mine 606
  - New Years mine 607
  - Boulder mine 607
  - The Giltedge mines 607
  - Cone Butte district 610
    - Collar Gulch 610
    - West Armell Creek 610
    - East Armell Creek 611
    - Head of Box Elder Creek 612
    - Cone Butte Mountains 612
    - East Fork of Maginnis Creek 613
    - West Fork of Maginnis Creek 613
- Placers 613
- Iron ores 614
- Coal 614

ILLUSTRATIONS.

Page.
PLATE LXIX. Topographic map 446
LXX. Sedimentary rock types, Cambrian 466
LXXI. Sedimentary rock types, Siluro-Devonian and Cambrian jaspery limestone 468
LXXII. Maiden Canyon, Carboniferous limestone, thinly bedded 470
LXXIII. Maiden Canyon, Carboniferous limestone, massively bedded 472
LXXIV. Warm Spring 474
LXXV. Geologic map 485
LXXVI. Lewistown and Judith Mountains 486
LXXVII. Maiden from east 510
LXXVIII. Maiden from west 512
LXXIX. Spotted Horse Gulch 528
LXXX. Fort Maginnis 530
LXXXI. Thin sections of phonolitic rocks (tinguaite) 570
LXXXII. Geologic cross sections 578
LXXXIII. Geologic cross sections 586
LXXXIV. Maginnis mine 600
LXXXV. Spotted Horse mine 604
LXXXVI. Giltedge mill 610
FIG. 32. Index map to show location of Judith Mountain area 446
33. Diagram to show apparent conformity of stratified rocks 458
34. Section of bedded rocks of Cambrian age 468
35. Section of Mesozoic rocks of Judith Mountains 480
36. Stereographic sketch of Burnett Creek Basin 488
37. East-west section through the Burnett Creek dome and laccolith 490
38. Sketch map and section of Ruby Gulch 493
39. East-west section through New Years and Pyramid peaks 495
40. North-south section through peak east of Pyramid Peak 498
41. Cross section through Kelly Hill and triangulation point 2 miles northeast 499
42. Northwest-southeast section through Giltedge Peak and Alpine laccolith 509
43. Sketch of Sheep Mountain (on left) and Pekay Peak, seen from slopes of Maiden Peak 512
44. North-south section through the Warm Spring anticline 519
45. Stereographic sketch of Warm Spring anticline and laccolith 519
46. Section northwest and southeast through foothills and mountain summit, 2 miles northwest of Judith Peak 522
47. Geological sketch map of Spotted Horse Gulch and vicinity 526
48. Geological map of Black Butte 554
49. Cross section north and south through Black Butte, showing asymmetric laccolith 555

Page.
FIG. 50. Graphic representation of rock-type relationships ... 563
51. Ground plan of laccoliths of Judith Mountains ... 577
52. Mount Hillers type of laccolith (after Gilbert) ... 580
53. Judith Mountain type of laccolith ... 580
54. Diagrammatic section showing contact of porphyry and limestone and zone of ore deposition ... 600
54*a*. Ground plan of workings of Spotted Horse mine, October, 1889, from survey by G. T. Wickes; fourth, fifth, and sixth levels of later workings sketched in ... 603
54*b*. Spotted Horse mine; vertical section through shaft and workings, October, 1889 ... 604

GEOLOGY AND MINERAL RESOURCES OF THE JUDITH MOUNTAINS OF MONTANA.

By W. H. WEED and L. V. PIRSSON.

PREFATORY REMARKS.

By W. H. WEED.

The region described in this paper was first visited by me in 1894 to determine whether a detailed study would be warranted. The reconnaissance made at this time revealed the unusual nature of the mountain group, whose laccolithic intrusions and tinguaite rocks aroused a keen interest in the region. During this visit the mines were examined and fossils were collected from the different geologic horizons, those from the coal seams proving new and indicating the presence of Lower Cretaceous strata. Brief notes upon the region were published in 1896.[1] The study and mapping of the mountains were planned for the summer of 1896, but assignment to the study of the Butte district made it necessary that I should spend but a short time in these mountains, and the detailed mapping was intrusted to my friend and colleague, Professor Pirsson, who has spent part of several field seasons with me in Montana work.

An attempt has been made to so state facts and legitimate deductions that they will be readily understood by the general reader and to make the work as useful to the practical miner as possible. As the economic development of the mineral resources of the Judith Mountains is promoted by a knowledge of the occurrence of the ores and coal beds and their relation to the rock structure of the region, a detailed account is given of the stratified rocks and of the folds into which they have been warped by igneous intrusions. The bedded rocks of different geologic ages are easily discriminated from one another, as the different beds and distinct geologic horizons are of widely varying appearance and composition.

---

[1] Mineral resources of the Judith Mountains, Montana: Eng. and Min. Jour., May 23, 1896, Vol. LXI, pp. 496-498.

CHAPTER I.

By W. H. Weed.

INTRODUCTION.

The Judith Mountains are situated near the center of the State of Montana, as shown by the index map, fig. 32, and extend from 108° 57′ to 109° 25′ west longitude, and from 47° 03′ to 47° 18′ north latitude, these limits comprising the area shown on the accompanying map, Pl. LXIX. They form one of the mountain groups of the Great Plains of the Northwest, the nearest peaks of the Rocky Mountain front being 35 miles to the west. The Missouri River flows 34 miles north of the mountains, and its tributary, the Musselshell, as far south and east. Lewistown, the county-seat of Fergus County, lies at the southwestern base of the mountains, and the town of Maiden is situated in the center of the range. The region is remote from the railroad lines of the State, which are reached by a stage ride of 112 miles by the shortest route. Various stage lines run to Great

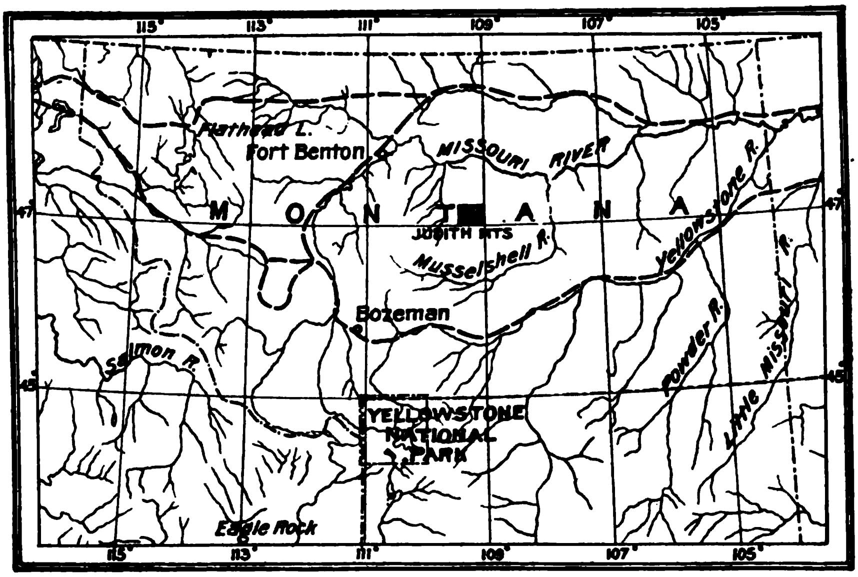
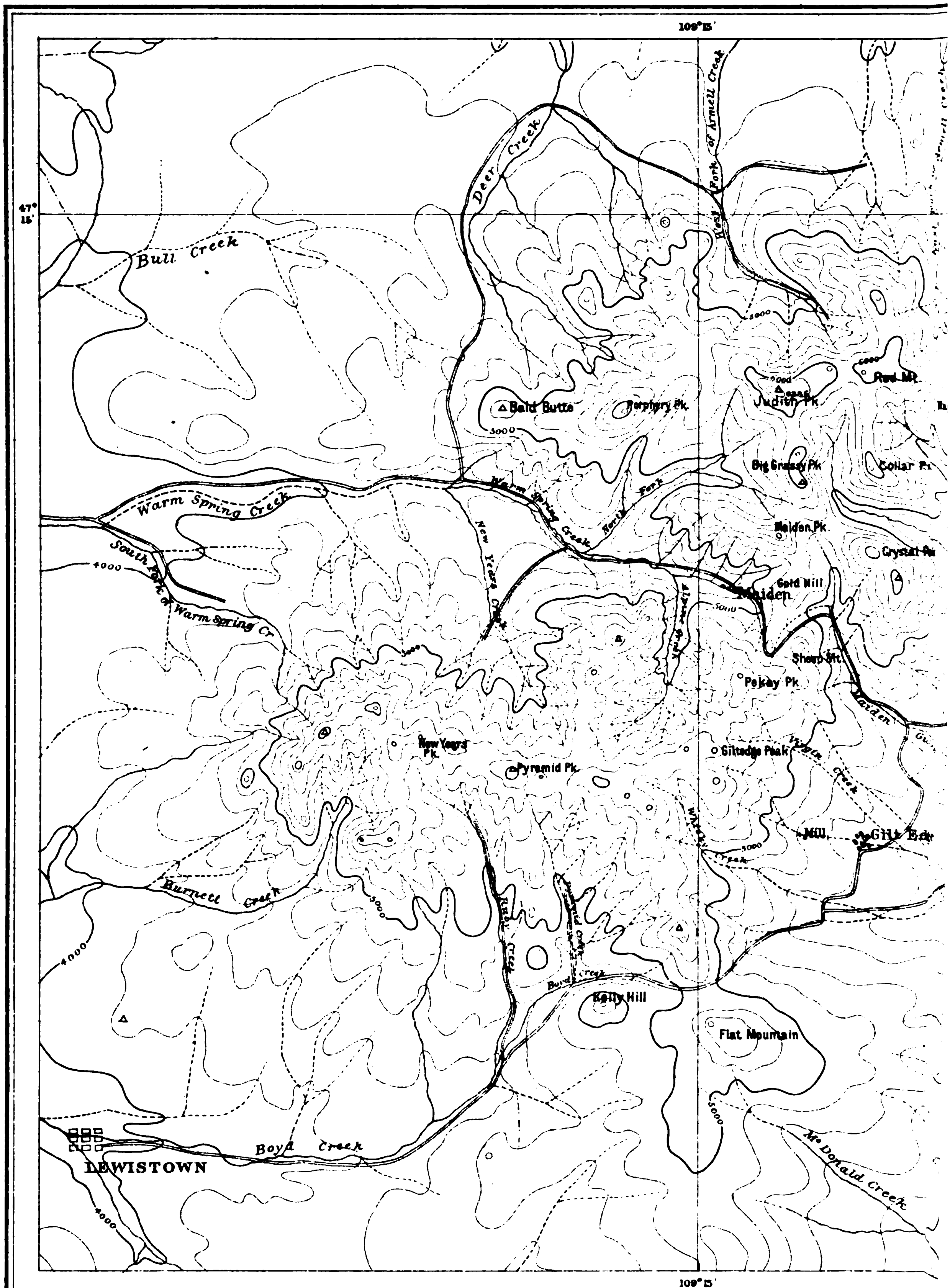


Fig. 32.—Index map to show location of Judith Mountain area.

U.S.GEOLOGICAL SURVEY



Triangulation and Topography by the
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TOPOGRAPHIC MAP OF JUDIT

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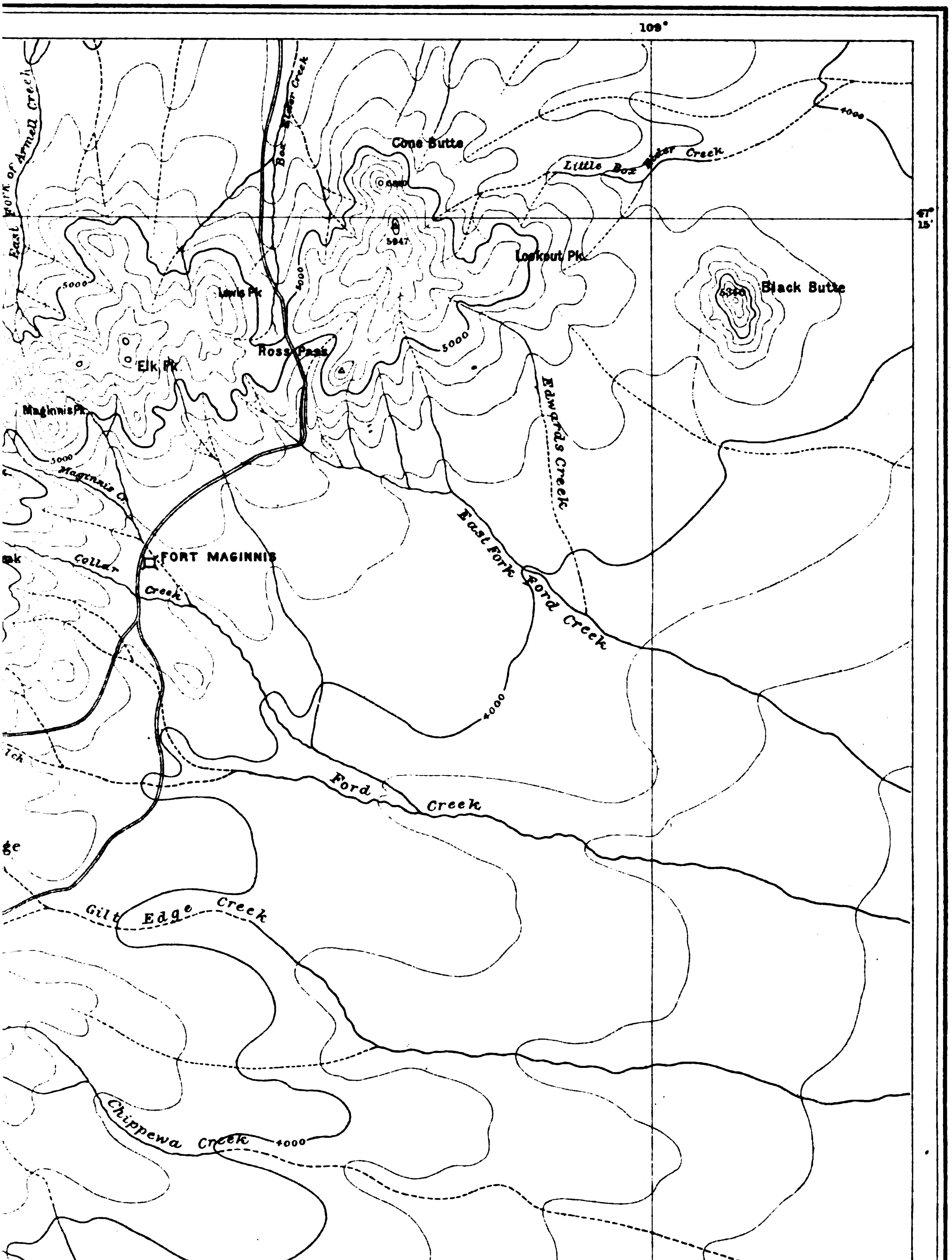

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H MOUNTAINS AND VICINITY

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Falls, Fort Benton, and Big Sandy, on the Great Northern Railway; and to Billings and Junction, on the Northern Pacific system.

The Judith Mountains rise like a great island above the plains which stretch eastward into central Dakota, and reach a height of some 2,500 feet above this level platform. They are impressive because of their solitary position and because their wooded flanks and rocky crowns are in strong contrast to the aridity and the flatness of the surrounding country. They do not constitute a range, as the term is generally used, but rather form a group of connected peaks and summits, extending in a general northeast-southwest direction for 18 miles and varying from 3 to 8 miles in width. The mountains are neither high nor rugged, the most elevated peak being but 6,386 feet above the sea, or a little less than 3,000 feet above the plains. They are therefore seen to be much lower than any of the other isolated mountains of the plains, except, perhaps, the Little Rocky Mountains, which lie to the north. South of the Judith Mountains the broad single dome of the Big Snowy Mountain rises to a height of 8,600 feet. To the west the two isolated peaks known as the Moccasin Mountains rise above the level plains, and beyond them is the broad Judith Basin. In the vicinity of the mountains wide terraces descend gradually to the general level of the plains (see Pl. LXXVI), and these higher tracts are generally well grassed and watered and fitted for cultivation, while the lower, more arid tracts are fitted only for sheep herders and cattlemen, who hold undisputed possession.

The scenery within the mountain tract is pleasing, being often picturesque, but never grand. Viewed from a distance, the range appears impressive, but within its boundaries the details of erosion are more interesting and more striking than the general forms of the mountain peaks. The surrounding plains are cut by the ramified trenches, tributary to the Missouri, and at no great distance from the mountains are dissected into the intricate Bad Lands, which, however, do not occur near the mountains. Gorges with abrupt limestone walls and sharply V-shaped valleys extending back into the mountain slopes are quite common features, but bold and sharp craggy peaks are not present. The country lies south of the glacial boundary, and no signs of local glaciation were observed. Projecting so far above the surface of the plains, the mountains act as local condensers of moisture and receive a comparatively generous supply of rain and snow. Springs are common, and the mountain area is clothed with luxuriant herbage and dense forests of pine. The climate shows the usual extremes of heat and cold common to this part of the State, but the summer is more uniform than in the Rocky Mountain tracts, so that a wider range of agricultural industries is possible within the mountain area. Few valleys are wide enough for settlement, the large valley of Warm Spring Creek being the only one suited for agriculture.

Of the early history of the region but little can be written. The explorers of the Northwest, Lewis and Clarke, followed the Missouri River, saw the Judith Mountains to the south, and named the river which has given its name to the mountains.[1]

The early history of the Judith region has been furnished me by Hon. Peter Koch, of Bozeman, Montana, who has written as follows:

> The region was traversed frequently by trappers and hunters all through the early part of this century, but the first visit by white men of which I find any record is by Father De Smet, September 13, 1846.[2] He gives an interesting account of a meeting within the basin of a peace congress of various Indian tribes.
>
> The next mention is in a report of the explorations of Lieut. John Mullan through the basin from west to east on July 22–25, 1860.[3] Before that, however, in September, 1853, it was visited by Lieutenant Mullan, who was sent out by Governor Stevens in the exploration for a Pacific railroad route to find a camp of the Flatheads, and who passed through the Judith Basin going out through the gap.[4]
>
> In 1869 Captain Clift, Thirtieth Infantry, surveyed a wagon road from Fort Ellis to the mouth of the Musselshell River, going through the basin, and a freight train went over it at this time. All this time there were no settlements of any kind in the basin.
>
> In the winter of 1872–73 Maj. F. D. Pease negotiated a treaty with the Crows, according to which they were to give up their reservation on the Yellowstone and accept in lieu of it the Judith Basin. This treaty was never ratified by the Senate and therefore came to nothing; but anticipating that this removal would take place, Messrs. Story and Hoffman, who were the traders to the Crows, engaged me to go down into the basin and establish a trading post. Captain Gross, an employee of the Crow Agency, went also to select a site for the new agency.
>
> A site was selected just below the mouth of Big Casino Creek, on the south bank of Big Spring Creek, and when the ox train with the goods and supplies had arrived I built there, during November and December, 1873, the first permanent houses within the Judith Basin. While waiting in idleness for the arrival of the train, the boys put in most of their time with an old deck of cards, playing casino, and we accordingly named the creek we were camped on "Big Casino" and a little spring creek just below "Little Casino," and I was much amused years after on seeing Colonel Ludlow's map that these names had been perpetuated.
>
> The basin was then the finest game country I ever saw, swarming with buffalo, elk, and deer. The white-tail deer were especially plentiful in the pine coulées which ran down through the foothills from the mountains, and their tameness showed that they had been very little hunted. Small bands of Crows came in to trade all through the winter, and we had considerable trouble from war parties of Sioux who came in to steal horses. One white man was killed by them.
>
> I left there in March, 1874, when it became evident that the removal of the Crows would not take place, and T. I. Dawes took charge of the post, which I had named Fort Sherman.
>
> That year Carroll was established on the Missouri River, and a wagon road was opened from that point to Helena, running through the basin. Meanwhile Major Reed, an old Indian trader, had purchased the trading store from Story and Hoff-

---

[1] See also map of Yellowstone and Missouri rivers, showing explorations of Captain Reynolds and Lieutenant Maynadier in 1859 and 1860, Washington, 1867.

[2] Oregon Missions and Travels over the Rocky Mountains in 1845-46, by Father P. J. De Smet, S. J., New York, 1847, p. 319.

[3] Report of Explorations of the Yellowstone River, by Bvt. Brig. Gen. W. F. Reynolds, Washington, 1868.

[4] Pacific Railroad Reports, Vol. XII, p. 123.

> man and moved it down Big Spring Creek about a mile and a half, to the crossing of the Carroll road, where it became known as Reed's Fort, and a hard place it was.
>
> A military post, Camp Lewis, was established in 1874, built, I believe, almost on the identical spot where I had built the trading post in 1873. Near this military post gradually sprang up a town, which is now Lewistown. the county seat of Fergus County.
>
> In 1875 Colonel Ludlow made a military reconnaissance from Carroll through the Judith Basin to the Yellowstone Park, and in his report is found the oldest map of the basin.

At the time of this last expedition, 1875, there were no towns in the region. The site of Lewistown was then occupied by an encampment of two companies of infantry known as Camp Lewis, the camp being established as the protection to the stage station on the road from Carroll to Helena, this being the route by which supplies were then brought into the State.

Lewistown, the county seat, is the largest settlement in this part of the State. It lies outside the mountain tract, but within the limits of the map. It is seen in Pl. LXXVI in the foreground, the mountains rising in the distance.

Maiden is the larger of the two settlements of the mountain area. It is situated in the valley bottom of the headwaters of Warm Spring Creek, environed by rapidly rising slopes showing no crags or rocky steeps, but generally smooth, mantled with a heavy growth of young pine trees where northerly exposures prevail, or grassy, with scattered groups of trees, on southerly slopes. This is shown in the two views, Pls. LXXVII and LXXVIII.

Mr. George H. Eldridge visited the region in 1882, in his exploratory surveys for coal for the Northern Pacific Railroad. A section made by him of the Mesozoic rocks between the Carboniferous and coal horizon 3 miles southeast of Maiden, and also a section on the flanks of the North Moccasin Mountain, have been published.[1]

The development of the region will be greatly hastened by railroad communication, but the chances of this seem at present somewhat remote. In the summer of 1896 mining was at its lowest ebb, but the future appears promising, and the known productiveness of the mines in the past will probably be largely exceeded when some of the more promising prospects have been developed.

A resource that is as yet comparatively undeveloped is the coal that surrounds the mountains. With an increase of population it is sure to command good prices as fuel for domestic and mill use. With the advent of a railroad to the region it will become a source of great wealth. Fire clays are found associated with the coal seams, and sand suitable for glass making is found in several localities, but these last two will never become great industries in the region.

---

[1] Tenth Census, Vol. XV, Mining Industries, p. 741.

CHAPTER II.

By Louis V. Pirsson.

TOPOGRAPHY AND HYDROGRAPHY.

THE MOUNTAINS.

Seen from a distance across the plains which surround them on nearly all sides, the Judith Mountains show a sharply serrated crest line, and have the appearance of a mountain range of the anticlinal type dissected by denudation. A series of quite sharp and distinct peaks rise with considerable uniformity to an average height of about 2,000 feet above the level plains country. The saddles between do not appear very deeply cut, but are sufficiently so to accentuate strongly the higher points. The mountain mass seems to rise sharply from the level country, like an island from the sea, the dark pine-covered slopes standing in strong relief against the wide and treeless plains of brown grass-covered country or the gray monotony of wide stretches of sagebrush flats. The mass of the mountains as thus defined from the plains forms an irregular elongated oval in its ground plan, the longer axis, with a length of about 20 miles, extending in a northeast-southwest direction, the shorter axis having a length of about 8 miles, which measures the greatest breadth of the mountains in a northwest-southeast direction.

Although the mountain group stands quite isolated, yet on the southwestern side there is a high and distinct ridge which forms a prominent watershed and extends directly southward until it merges into the general mass of the Big Snowy Mountain. The mountains form a very compact area, the only exception being Black Butte, a separate, detached elevation about 2 miles away from the eastern end of the range. This butte was known in former times by the name of Buffalo Heart Mountain, a name now obsolete.

About 6 miles west of the Judith Mountains rises the southernmost of the two Moccasin Mountains, separated by a broad, smooth, open valley. This is the nearest mountain neighbor; it is in many respects a miniature of the Judith group and might be considered as a part of it.

The mountains are everywhere sharply bounded by easily eroded rocks, and owe their dominant and well-defined topography to heavy and resistant rocks. In fact, the dependence of topography upon geologic structure is extremely close, and it is almost impossible to describe one without mentioning the other. Topographic details will therefore be freely given with the description of the geology.

A study of the topographic map (Pl. LXIX) shows that the western end of the range is formed of a curving, horseshoe-shaped ridge, or, in fact, a mountain with a large funnel-shaped basin which discharges to the southward. This is connected on its upper bend, by an eastwardly running ridge, with another circular and somewhat larger horseshoe ridge, whose amphitheater drains northward. At the point where the connecting ridge and the last-mentioned horseshoe come together another ridge starts southward, which eventually passes out on the very broad, flat-topped divide known as Flat Mountain. Eastward and northward of the eastern horseshoe ridge drained by Alpine Creek there is a low divide, and beyond this the country is broken, with less regularity of plan, into a group of peaks with low-cut connecting divides and deep valleys between.

The highest point in the mountains is found in Judith Peak, which rises to 6,386 feet above sea level (by triangulation), or about 2,500 above the general average of the open plains country. From this peak a main divide extends eastward, throwing out several prominent spur branches and having a winding course with an irregularly rising and falling crest line, until it ends in a high point (Lewis Peak) overlooking Ross Pass. This latter, with an elevation of about 5,000 feet, is the lowest and broadest divide or pass through the mountains, and eastward of it they again rise sharply into a single grouped mountain mass, on the north side of which is Cone Butte. Beyond this rises Black Butte, previously mentioned, the last elevation fronting on the great plains country, which sweeps in unbroken continuity eastward.

The open Cretaceous plains country that surrounds the mountains has a more or less rolling, gently contoured surface. Toward the streams it is cut by wash gulches, and presents the usual types of topography caused by the erosion of practically level, easily eroded strata. Its character is seen in several of the accompanying illustrations, and especially in Pl. LXXVI; it is that so commonly found in our western plains country and so characteristic of large portions of that region.

Toward the mountains this open country gently rises until the mountain uplift is reached; at this point there is generally an outer fringe of small, low, sparsely wooded foothills, and beyond these the slopes of the mountains themselves rise abruptly and with a very steep angle of slope directly to the upper crest line. Although steep, they are rarely precipitous, and the divides also, though generally narrow, are almost never precipitous, but may be traveled on foot or with the horse in all directions except where heavy growths of young pines prevent.

VALLEYS AND STREAMS.

From the geographic position of the Judith Mountains it is clear that all of the waters drained from its slopes fall into the Missouri River, but of the various streams Armell Creek is the only one that enters it directly, the others passing first into the Musselshell River or the Judith River. The drainage systems are simple, and extend radially outward from the main streams.

CLIMATE AND RAINFALL.

The climate is, on the whole, dry and of a somewhat semiarid nature. It shows great extremes, ranging from very hot in summer to extreme cold in winter, the total range being as much as 160° F. It is liable also to sudden changes. In the mountain tract proper, however, these extremes are considerably mitigated, and owing to the isolated position of the mountains they have a much greater rainfall than the surrounding plains country, a heavier snowfall in winter, and frequent thunder showers during the summer.

CHARACTER OF STREAMS.

In spite of the fact that there is a large amount of precipitation in the form of snow during the winter and considerable in that of rain during the summer, the streams, for the size of their catchment basins, carry surprisingly little water, or even none. The mountains, it is true, are below the level of perpetual snow and there are no snow banks lasting through the summer to act as perennial stream feeders, but a much more potent reason for the scanty supply of water is to be found in the geologic structure. As the water sinks, it reappears as springs only in the areas of shale; in those of limestone it does not often soon reappear, and streams entering the limestone areas are liable to sink from sight. The water thus passing down beneath the beds of limestone finally emerges in the channels of the most considerable streams as large and powerful springs. One of these is shown in Pl. LXXIV. The result is that within the mountain tract the streams in summer have running water in their beds only in the areas of porphyry or of Cretaceous shales; in the limestones they are dry, or on entering limestone belts rapidly become so.

The western side of the mountains is drained by Boyd and Burnett creeks, branches of Big Spring Creek, a considerable fork of the Judith River.

Boyd Creek is a running stream in its entire course from the divide east of Kelly Hill. On the south it receives accessions from a number of springs which break out in the Cretaceous hills and which ooze along downward in muddy rivulets banked with fresh grass on either side, the course of the drains being thus marked by lines of winding, vivid green on a background of brown or russet-colored bench lands or slopes of country covered with dried grass. Such drains are favorite resorts of the herds of sheep or cattle, which trample them to a muddy ooze. This, indeed, is the character of these Cretaceous hillside runnels throughout the mountain area.

On the north side the long and winding valleys of Ruby and Pyramid gulches are dry, except in a little area of Cretaceous shaly beds toward the head of Ruby Gulch, where small springs burst forth, only to disappear in the course of a few rods as they pass into the limestones. The waters thus drained underground in the various forks of Boyd Creek on its north side come up as powerful springs in the bed of the main creek lower down.

Burnett Creek derives its waters from the amphitheater at the west end of the mountains. The deep and narrow gulches in porphyry and slate are dry in summer, and it is only just before the limestone canyon which forms the gateway from the large interior funnel-shaped basin is reached that the water breaks out in springs, giving sudden rise to an active brook which sends its waters across the plain to join Big Spring Creek.

Warm Spring Creek heads near the town of Maiden in springs which issue from the divides and slopes of Cretaceous strata filled with porphyry sheets and intrusions, east and north of the town. It passes down a deep V-shaped valley, whose character is admirably seen in Pl. LXXVII, and receives a considerable amount of water from Alpine Creek, which drains an interior funnel-shaped basin, cut by deep and narrow gulches, precisely like that at the head of Burnett Creek. The North Fork, which drains a rather flat-floored valley with sudden, precipitous slopes of porphyry and shale, flows a volume of water greater than that of the main stream, much of whose current is really underground. New Years Gulch presents a gathering of narrow canyon-like valleys which are cut in limestone, and consequently dry. There are a few springs as the Cretaceous is reached, but the main outflow is a mere seepage, and little or nothing comes into the Warm Spring in the summer season. In the main stream the volume of water rapidly diminishes from that of a fair-sized brook until, at the point where it passes out of the mountains and on to the west side of the anticline, shown on the geologic map (Pl. LXXV), through which it cuts, it runs in the summer entirely dry, sending its water over the plain only in season of flood. The large amount of water passing underground is shown about a mile west of the last point, on the edge of the map, where a large and powerful and rapidly running creek, a couple of rods or so across and several feet in depth, breaks out in a huge spring in the valley bottom. A view of this spring is given in Pl. LXXIV. The spring, from the very constant and somewhat elevated temperature of its waters, is known as Warm Spring and gives its name to the creek. Bull Creek, which is one of the

Warm Spring branches, is one of those oozy seepages in the Cretaceous hill country described above.

Armell Creek drains the north slopes of the mountains, and its various branches are shown on the map. Most of them are small, clear, running streams. The west fork, which drains the amphitheater north of Judith Peak, passes an area of upturned and lifted limestone through which the creek has cut a short canyon, and although some of the water undoubtedly sinks, the main body passes over to the Cretaceous shales beyond. The waters west of this fork and between it and Warm Spring Creek form a large branch, which joins Armell Creek some distance below the junction of its forks and is known as Deer Creek.

Box Elder Creek is a long stream, which winds through the open country to the eastward to join the Musselshell River. It receives its waters chiefly from the mountain mass south of Cone Butte, which, as may be seen upon the map, is dissected radially by a number of valleys which are deep, narrow, V-shaped, and cut in porphyry or shale. In them the streams, which, though small, are bright and running, head back in springs. The headwaters inclose this mountain mass on all sides, and hence take the drainage of Ross Pass on both slopes.

Streams on the south side of the mountains.—The various drainage areas on the south side of the mountains form the headwaters of Ford and McDonald creeks, both of which, like Box Elder, are branches of the Musselshell River. All of these headwaters are small brooks, running throughout the year when in shale or porphyry, as noted above, but disappearing in the limestone areas. This is the character of Collar Creek, which rises in the steep gulches south of Judith Peak and Red Mountain, and also of Maiden Creek, which rises in the beautiful mountain parks between Crystal and Maiden peaks, and, entering the limestone, cuts in the mountains the most considerable canyon, at the mouth of which the water sinks. Along this portion of the mountain area the streams which send their waters to the plain are apt to sink into the heavy accumulations of wash gravel which lie in their courses, and thus in general they are seen running in their channels chiefly in times of flood. The steep gulches cut back in the limestones in which Virgin, Giltedge, and Whisky creeks take their rise are dry and waterless, and only when the lower country is reached do the small seepages begin. In some of the limestone areas, indeed, the drainage appears so completely underground that there is not even an open flood channel, a dry, uninterrupted meadow extending from slope to slope. This is the case in portions of the valleys of Ruby and Pyramid gulches, mentioned above.

Valleys.—Owing to the small size of the mountains there is no large valley in them, that of Warm Spring Creek being by far the most considerable. They are generally short, deeply cut, and with rapid ascents at the heads to the divides.

FORESTS.

Owing to their position in an open, treeless country, whose stream bottoms have been mostly occupied by ranches, and surrounded as they are by a not inconsiderable, permanent population, the Judith Mountains assume each year a more important position with regard to their forest growth. They must supply to the country round about lumber, fencing, and in no small degree fuel, and the margin of profit of many mining ventures will depend largely on the nearness of an available timber supply.

There are no large and heavy forests in these mountains, but a very considerable growth of timber is everywhere to be found. The débris slopes of porphyry are almost invariably covered with a thick, matted growth of young pines (*Pinus contorta*), called "bull pine" in popular parlance. When they have attained some growth these pines form dense and tangled thickets, almost impenetrable without the use of the ax, either on foot or on horseback. Such dense thickets are especially apt to spring up after the heavier original forests have been leveled by fire or storm. On the porphyry areas they are so general that they serve as a useful means of geologic reconnaissance. The northern and western interior slopes of the basins of Burnett and Alpine creeks are heavily clothed with them.

The large timber of the mountains has been mostly cut off for building and mining purposes. Such as now remains is found in scattered groves in the foothills, especially those composed of Jurassic strata. Generally throughout the mountains, in the interior of the gulches, the northern slopes of the hills, and the outcrops of sandstone there is more or less of a forest growth of conifers. The most abundant species is *Pinus contorta*, the "lodge pole" or "bull" pine, which seldom attains a sufficient diameter to be useful for lumber, but serves well for fencing, fuel, or lagging. The Engelmann spruce and Douglas fir (*Pseudotsuga douglasii*) form the largest timber trees, but have been mostly removed from the vicinity of the mines and settlements, and timber exceeding 18 inches in diameter is found in but very few places. In the lower stream bottoms is found the cottonwood, with thickets of black alder, willows, and bushes of various kinds. In Collar Creek the white birch was noted.

While, therefore, there are no large forested areas left in this region, there is a very considerable amount of valuable timber still standing in various localities. Its value is fully recognized by the resident population, but as there is no private title to the greater part of it it is often improvidently and wastefully cut, sometimes for speculation, by those who have no permanent interest in its care or preservation.

ROADS.

Well-traveled routes run out from Lewistown in various directions, and toward the mountains in two ways. The southern route is up Boyd Creek, over a divide, and to the town of Giltedge. From here one branch of it leads up Maiden Canyon to the town of Maiden, while another goes to Fort Maginnis and on through Ross Pass down Box Elder Creek. Prominent roads run down the main streams, whose heads are shown on the map. On the north side the road from Lewistown, passing through the open country on the route to Fort Benton, turns and goes up Warm Spring Creek to Maiden. A branch passes through the foothills toward Armell Creek and reaches Box Elder Creek. In the mountain area itself wagon roads are cut in various directions. They ascend every gulch, pass over many of the divides, and connect many of the valleys. Some are good, others are mere trails suitable for horseback riding. Thus all parts of the mountains are readily accessible and may be traveled with ease.

CHAPTER III.

By W. H. Weed.

GENERAL GEOLOGY.

STATEMENT OF PROBLEM.

The Judith Mountains form an isolated, independent mountain group, separated by the lower plains country from the nearest mountain masses and from the distant front of the Rocky Mountains. It is as independent and complete in its geologic structure as in its geographic relations. The group is formed by a number of independent, coalescing, dome-shaped uplifts, involving the sedimentary series from Cambrian to Cretaceous, with laccolithic and other intrusions of igneous rocks.

Geographically and geologically the study of the region constitutes a problem complete in itself. The mountains are of comparatively recent geologic age, and there is no evidence to show that the area was an island in the Paleozoic or Mesozoic seas; but the facts indicate that the site was but a part of the plains area, at least until after the deposition of the earlier Cretaceous sediments.

The geologic history of the region must be determined from a study of the sedimentary rocks and their fossils, together with the structural forms in which the rocks are now found. The oldest rocks exposed are of Middle Cambrian age. The earlier rocks, of Archean, Algonkian, and Lower Cambrian age, if present, are yet deeply buried. The Paleozoic sediments are all of marine origin, and a comparison of the beds with those observed elsewhere in Montana shows that the strata form a part of the Rocky Mountain area of sedimentation. The formations are, however, much thinner, and agree with those observed in the Little Rocky Mountains, farther north, in showing a thinning out of the Paleozoic terranes east of the Rocky Mountain front.

The sedimentary rocks are apparently conformable from the Cambrian to the Cretaceous age. No angular unconformity of dip or irregularity of strike or evidence of unconformity by erosion has been observed. Unconformity is so uncommon in the stratified rocks of the northern Rocky Mountain region[1] that it seems well to consider, in the light of the evidence of elevation and erosion afforded by the rocks themselves, why it is not observed in these easterly areas of the Rocky Mountain province.

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[1] Geologic Atlas U. S., folio 1, Livingston, Montana; folio 24, Three Forks, Montana; folio 30, Yellowstone National Park, Wyoming.

Unconformity.—To geologists familiar with the upturned and folded beds of the Atlantic border, where angular unconformity and unconformity by erosion are phenomena frequently observed, it often appears that the evidence presented in the West is not conclusive proof of actual unconformity. In fact, however, it is rather remarkable that such marked angular unconformity has been recognized, for it is evident, upon consideration, that it is only along the actual shore line, where transgressing sedimentation has covered the eroded edges of earlier beds, that such unconformity will be recognized. This will be readily appreciated by a glance at fig. 33. The earlier strata are steeply upturned along the mountain flanks, as is actually the case at the east foot of the Rocky Mountains. This folding dies out gradually east of the mountains, until over the area of the plains the beds are level that are so steeply upturned in the mountains. Hence the new sediments rest upon the earlier beds in perfect conformity a few miles east of the mountains. For this reason we should not expect to find recognizable unconformity in the strata of the Judith region, though the beds might represent two periods separated by an interval of nondeposition and uplift far to the west.

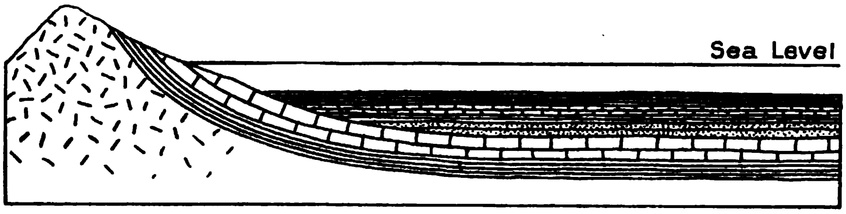

FIG. 33.—Diagram to show apparent conformity of stratified rocks.

PALEOZOIC HISTORY.

The Paleozoic exposures of the Judith Mountains afford the only available data concerning the thickness and character of the eastward extension of the Paleozoic rocks of the Rocky Mountains beneath the plains. A consideration of the sections measured in this region shows a marked decrease in thickness from that prevailing in the nearest range of the Rocky Mountains on the west or those south of the Yellowstone River. This is most noticeable in the Cambrian section, where the rocks are all of shallow-water or littoral origin. The known absence of Paleozoic rocks beneath the Cretaceous strata of Dakota, as shown by artesian-well borings, would suggest the possibility of an early land mass in that region which supplied the sediments deposited in the Cambrian and late seas.

CAMBRIAN TIME.

The Cambrian rocks are shales, cherty limestones, and limestone conglomerates, aggregating about 500 feet. As the base is not known, this does not fix the total thickness of the terrane, but the horizons are so well defined and the sequence is so definite that comparison with the Cambrian sections of other parts of the State is readily made. The rocks consist of detrital material—clay, quartz sand, and silt—worn from the land and distributed by ocean currents and waves. The material composing these Middle Cambrian rocks was not directly derived from the erosion of Archean land masses, appearing to come rather from the erosion of earlier sediments.

SILURO-DEVONIAN TIME.

The limestone conglomerates are significant, consisting of flat beach pebbles which show the erosion of a bold and abrupt coast in which earlier limestone sediments were exposed to erosion, so that the region must have undergone local uplift before this time.

The micaceous character of the shales shows that erosion was rapid and that the rock decay had not taken place on the land. The Cambrian rocks show deposition along the shores of shallow off-shore reaches, succeeded by conditions favoring the accumulation of limestones.

Throughout Silurian and Devonian times the site of the Judith Mountains continued beneath the sea. During the Silurian, oscillations of level, or a rise of the bottom due to sedimentation, caused the deposition of beds of arenaceous limestone. The rocks are colored dark by organic matter. Following this the conditions were favorable for the formation of limestones, and these rocks alone were formed until the close of Lower Carboniferous time. These limestones carry fossil remains of corals, crinoids, and other marine animals characteristic of relatively shallow water.

CARBONIFEROUS MOVEMENT.

At the close of Lower Carboniferous time an elevation of this region, as well as of the eastern part of the Rocky Mountain region, occurred. No evidences of dynamic disturbance have been noted, but the submerged region was raised above sea level and exposed to erosion. The correlated evidence from other parts of the State seems to show that the movement was differential, resulting in varying elevation throughout the raised tract. This movement is supposed to have occurred at the close of the Lower Carboniferous or the beginning of the Upper Carboniferous period, as there appears to be an absence of beds of the latter age in the Rocky Mountain region, and if beds of this age were deposited in the Judith Mountains they were certainly removed by erosion before the region was again submerged beneath the sea.

Observations made in the Little Belt range seem to prove that the close of the Lower Carboniferous epoch was marked by an elevation, and that the areas studied were lowlands during the time represented by the Upper Carboniferous. The Quadrant formation, which is the highest of the Carboniferous horizons of the Yellowstone Park and Livingston region, consists of alternating beds of sandstone or quartzite and of limestone. In the vicinity of Tiger Butte, north of the Little Belt range, the uppermost Carboniferous beds are silty shale and sandstones, containing gypsum beds, all indicating shallow waters, near-by land, and evaporating waters in tidal reaches. The thickness of the section, otherwise comparable, varies, and higher beds are found at some localities than at others, indicating erosion and partial removal of the higher beds before the next succeeding strata were laid down.

No Permian or Trias sediments occur, and the region was probably a land area during these periods. The Red Beds, so prominent in Wyoming and Colorado, appear in the Yellowstone Park section, but thin out and have not been recognized farther north. It is necessary to emphasize this fact because numerous exposures of red clays and associated sandstones of other horizons are seen about the Judith Mountains.

POST-CARBONIFEROUS MOVEMENT.

The movement by which this tract was again submerged was very uniform, as no discrepancy of dip and strike has been recognized between Carboniferous and Jurassic beds. The Ellis[1] beds were deposited during this depression. The earlier beds are limestones, succeeded by calcareous shales, with intercalated beds of arenaceous material, succeeded by a sandstone, varying to a limestone, that is a shore deposit. The fauna is well marked, essentially marine, and resembles, in species and assemblage, the fauna characteristic of the Jurassic in this province. The beds show a shallow and gradually rising sea, the movement being the beginning of a period of elevation which may be called the pre-Cretaceous movement.

PRE-CRETACEOUS MOVEMENT.

The pre-Cretaceous movement resulted in the formation of areas of low land, with broad marshes and bodies of fresh water. The sediments designated Kootanie and correlated with the formation of that name in the Canadian region are of fresh-water origin. Sandstones and red clay-shales derived from the washing away of residual clays show low land and prolonged rock decay. The beds are not persistent in character, varying from shale to sand rock horizontally as well as vertically. A coal seam formed in this period was accumulated in connecting marshy basins, and the ferns and cycad leaves show low land and a warm climate. A succeeding limestone carrying fresh-water shells was formed in bodies of fresh water that covered coal marshes and sandy flats alike. During this period dynamic disturbances of great moment occurred in the northern Rocky Mountains, where volcanic accumulations several thousand feet thick are found. No record of such disturbance is observed in the Judith section.

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[1] Formation name of Jurassic beds in Montana.

EARLY CRETACEOUS MOVEMENT.

A further movement must have occurred at the close of the Kootanie period, resulting in the elevation of the land and the cessation of deposition. That the period was a prolonged one is evidenced by the lack of sedimentation during the time that the Comanche series of Texas was being formed—a series whose representative has not yet been discovered in the Rocky Mountain region of Canada or Montana.

MIDDLE CRETACEOUS MOVEMENT.

Whatever may have been the conditions prevailing during the latter part of Lower Cretaceous time in the area of the Judith Mountains, this period was followed by a depression which marked the beginning of Upper Cretaceous time. The earlier sediments, the Dakota sandstones, record a gradually spreading beach and an ocean advancing over an area long exposed to subaerial decay and disintegration, for the clays and silty sandstones show low land and deep soil. No unconformity is recognized between these beds and those of the preceding age, but rather an essential conformity of dip and strike which, together with the similarity of the beds, make discrimination uncertain and arbitrary. Indeed, the lack of fossils from this region makes recognition of the age of the rocks somewhat questionable. The sandstones are, however, the earliest beds of the cycle of deposition which includes the succeeding Benton shales and Niobrara limestones.

COLORADO TIME.

The Benton shales, which form the earlier deposits of this period, are of marine formation and are characterized by an extensive fossil fauna at the type locality, which gives the formation its name, some 75 miles from the mountains. The presence of fish scales and other marine fossils in the Judith Mountains shows that marine conditions prevailed over this area. The beds are mainly argillaceous shales, dark-gray or black, and often bituminous. They carry calcareous and ferruginous concretions that are fossiliferous and are sometimes characterized by pyrite or an efflorescence of gypsum, and they are the source of bitter gypsiferous springs.

The Niobrara and succeeding Cretaceous sediments occur about the Judith Mountains, but not within the area mapped and discussed.

They present a record of varying sedimentation, ending with fresh-water beds of Laramie age. The evidence seems to favor the view that these beds, except the Laramie, formerly covered the site of the Judith Mountains.

POST-CRETACEOUS MOVEMENTS AND MOUNTAIN-BUILDING.

The beds about the mountains are essentially horizontal. Although, as just stated, they have been at different periods lifted above sea level and exposed to erosion, the series is essentially conformable in dip and strike from Cambrian to Lower Cretaceous, as no evidence of flexure previous to the time of the formation of the Judith Mountains has been recognized. At some later period, which was post-Laramie and pre-Miocene, the previously horizontal sedimentary beds were uplifted in a number of great blister-like anticlinal domes, the rocks being crumpled and bent, in places broken by faults, and split apart by intrusive bodies of molten rock, which rose up beneath the arches and spread out as sheets, or very rarely filled fissures as dikes in the disturbed beds. There is no record whatever of any volcanic outburst. If such extrusive rocks ever existed they have been completely removed by denudation. These igneous intrusions caused the overlying strata to arch above them, but over much of the mountain area the softer shales and sandstones have been removed, and to-day the more resistant Paleozoic rocks are exposed over much of the area. That the height of the mountains was formerly much greater can not be doubted. In the general degradation of the mountain tract this area, because of its greater altitude, has been worn down rapidly as long as the rocks were soft and readily removed; but when the harder rocks were reached the rate of degradation became less than that of the surrounding plains, and to-day the softer beds are found about the mountain flanks, occurring in the higher areas only where they have been involved in folds.

There is no record showing the history of the region during Tertiary time. Judging by analogy, it is supposed that the intrusions and uplift occurred in Eocene time. In general the topography of the mountains of Montana is relatively old. The mountain systems were blocked out and eroded into almost their present shape during Eocene time, for Miocene lakes existed in the present Rocky Mountain valleys, and their deposits are to-day almost undisturbed and, with succeeding Pliocene lake beds, are not materially eroded. That energetic degradation was in progress in the region immediately east of the Rocky Mountains is, however, certain, for the Crazy Mountains, one of the detached mountain groups of the plains, is formed of Eocene strata cut by dikes and batholiths of igneous rock of post-Miocene age,[1] and now eroded into a mountain group whose peaks are 7,000 feet above the plains at their base.

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[1] Bull. U. S. Geol. Survey No. 139, 1896, pp. 78, 109.

The intrusive masses of the Judith Mountains are of the greatest interest, and their nature and structure will be fully discussed in a later chapter. In general the mountains may be said to be laccolithic; that is, they are due to a number of dome-shaped uplifts with laccolithic intrusion of igneous rock. The degradation of the region has exposed numbers of these bodies, but has not usually progressed far enough in the large ones to uncover their bases, so that their shapes and thickness can only be inferred. Nor has erosion yet developed the laccoliths that presumably underlie the domed arches which are a common feature of the mountains. It is at once seen that the structure is different from that of most mountain groups, or even that of the other island mountains of the plains, but is similar to that of the nearby Moccasins, which may be considered a part of this group, and the Sweet Grass Hills, near the Canadian border. The other mountain groups of the plains are either volcanic piles, erosion mountains, or, as in the case of the Little Rocky Mountains, one great quaquaversal dome uplift, not of laccolithic origin.

In the southern half of the mountain group the igneous intrusions appear to be laccolithic in character, and the horizon invaded by the larger bodies has been the shale beds of the Cambrian. This is not usually the case in the vicinity of Judith Peak and the mountains east of it. Here the intrusions are much more irregular and break across strata of different ages, though largely intruded in Cretaceous rocks. Though two distinct intrusions are recognizable, they probably belong to but one epoch. The results of the earlier are seen in the laccolithic masses and sheets and stocks of porphyry and the allied rocks. The later was that during which the tinguaite sheets and dikes were intruded in the porphyry and the Cretaceous shales. There is a marked scarcity of dikes of the earlier period of intrusion as compared with the laccolithic mountains of Colorado. The bodies of granular rocks found near Judith Peak may represent a somewhat different phase of the same period of igneous activity.

Following the period of uplift and intrusion of igneous rocks, ore-bearing solutions brought their burden of precious metals into the rocks. In general it is assumed that such waters follow the easiest course. For this reason the contact planes between igneous and sedimentary rocks were often followed, since differential shrinkage produced incipient fracture, which offered an easy channel, but the impervious porphyry prevented further permeation. In the larger intrusions shrinkage planes in the porphyry itself were also channels for ore-bearing waters. The Spotted Horse and Maginnis ore bodies lie in the altered limestone near the contact of the Gold Hill mass of porphyry, and the Giltedge ores are found in the limestones beneath intrusive sheets.

The denudation and dissection of the mountains, laying bare the structure and mineral deposits, is the last phase of their geologic history, and one that is still going on. In this process the higher laccoliths have been bared, and, while others remain protected by the overlying strata, the soft Cretaceous rocks have been pared away from the intruded mass in the north, and the hard igneous rocks form the highest points of the mountains. The latest effects of erosion are shown in the beautiful gradation terraces which are found about the mountains, and which are particularly well developed in the vicinity of Lewistown.

Whatever may have been the original drainage in this area, it was probably changed and a new system developed upon the uplifting of the domes. The degradation must have been rapid, as the beds were soft, and the increased elevation subjected them to increased vigor of attack. When the Carboniferous limestones were reached in the southerly area, they yielded more slowly to attack. Elsewhere the hard and resistant porphyry was uncovered. Upon this erosive agencies worked but slowly, and erosion has since tended to emphasize the high points, while degradation of the flanks was increased by the addition of igneous débris to the stream gravels, since this harder, resistant material increased the rate of stream cutting. The rocks of the higher summits do not afford a picturesque or rugged topography, but form rounded summits, owing to the small-sized débris into which they are split by frost.

The region is situated south of the limits of the continental ice sheets, and no positive evidences of local glaciation have been observed. The topographic forms, however, are complicated, and are not those due to uninterrupted erosion of the uplift. Differential erosion produces a variety of forms, but it seems evident that the uplifts and depressions that have occurred in the plains region since Laramie time have influenced the character of the topography here, as well as out upon the plains.

PALEOZOIC STRATIFIED ROCKS.

The sedimentary rocks of the Judith Mountains cover more than two-thirds of the entire area. In the southern part of the mountains, south of the town of Maiden, the older sedimentary rocks dominate the topography and form the higher points and summit plateaus. In the northern summits the igneous rocks form Judith Peak, the highest point of the mountains, and its adjacent summits, and the topography is in strong contrast to that of the sedimentary areas. The peculiarities of topography and vegetation due to the difference in rock structure are so strong that in many cases the character of the rocks can be correctly inferred from the surface features.

The stratified beds are marine sediments and appear to be perfectly conformable. This has been found to be true of all the Paleozoic and Mesozoic sections studied by me in Montana, the great mountain-building epoch beginning at the close of the Laramie. The soft beds of shale and sandstone which form the surrounding plains have been removed from a large part of the mountainous tract, laying bare the intrusive masses of porphyry and the heavy beds of white Carboniferous limestone which now form the mountain summits. The larger streams have cut still more deeply into the rock domes, exposing lower beds and the igneous masses which form the core of the uplifts. The stratified rocks thus exposed by the degradation of the mountain uplifts include strata belonging to all the great geologic periods from Cambrian to Cretaceous, the strata resting in apparent conformity upon one another. Sections of the stratified rocks will be given in detail, so that the thicknesses may be used in tracing out definite horizons at which ore or coal occurs. Such horizons are frequently concealed by soil, débris, or vegetation, while the overlying and underlying beds are exposed. When this is the case, the intervening thickness being known, the desired bed can be readily located.

CAMBRIAN ROCKS.

The oldest sedimentary rocks of the Judith Mountains are found about the headwaters of Burnett, New Years, and Alpine creeks, which have cut deeply into the cores of the dome-shaped uplifts, exposing the older rocks, together with intruded sheets of porphyry and greater laccolithic masses of igneous rock. The lowest strata exposed are of Cambrian age. The rocks, though greatly toughened and altered by the intruded porphyry, show that their original character was that of soft micaceous and limy shales, quite like the Cambrian shales of the eastern front of the Rocky Mountains. These soft beds afford but little resistance to the intrusion of igneous rocks, and therefore are frequently found in Montana to be altered and toughened by such intruded masses.[1]

In general, the rocks assigned to the Cambrian show a marked resemblance to those of the same age occurring in the Rocky Mountain ranges to the west and in and near the Yellowstone Park. The rocks are quite thinly bedded and are argillaceous, but contain siliceous beds near the base and thin irregular masses of limestone, whose ready weathering causes the joint planes to show a ribbed or reticulated surface in relief. These features, though hard to describe, are very characteristic of the rocks of the Cambrian of Montana, which differ widely from those of any other horizon.

As will be seen by reference to the accompanying geologic map (Pl. LXXV), Cambrian rocks are exposed on a comparatively small part of the mountains. At each place where they occur the rocks are much altered by the adjacent masses of igneous rock, and the soft shales have been changed to tough, dense, and brittle hornstone or hard and sonorous slates, and, though no slaty cleavage is developed, there is a strongly marked set of small joints, so that the original bedding is sometimes recognizable only by careful inspection of the color bands. This contact metamorphism is not extreme, and is greatest near the contact with the porphyry intrusion. As, however, the porphyry is not absolutely regular in its intrusion, occurring at a varying and irregular horizon and in sheets that thin out, the rocks of certain beds are not equally altered at all places.

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[1] Bull. U. S. Geol. Survey No. 139, 1896, p. 62.

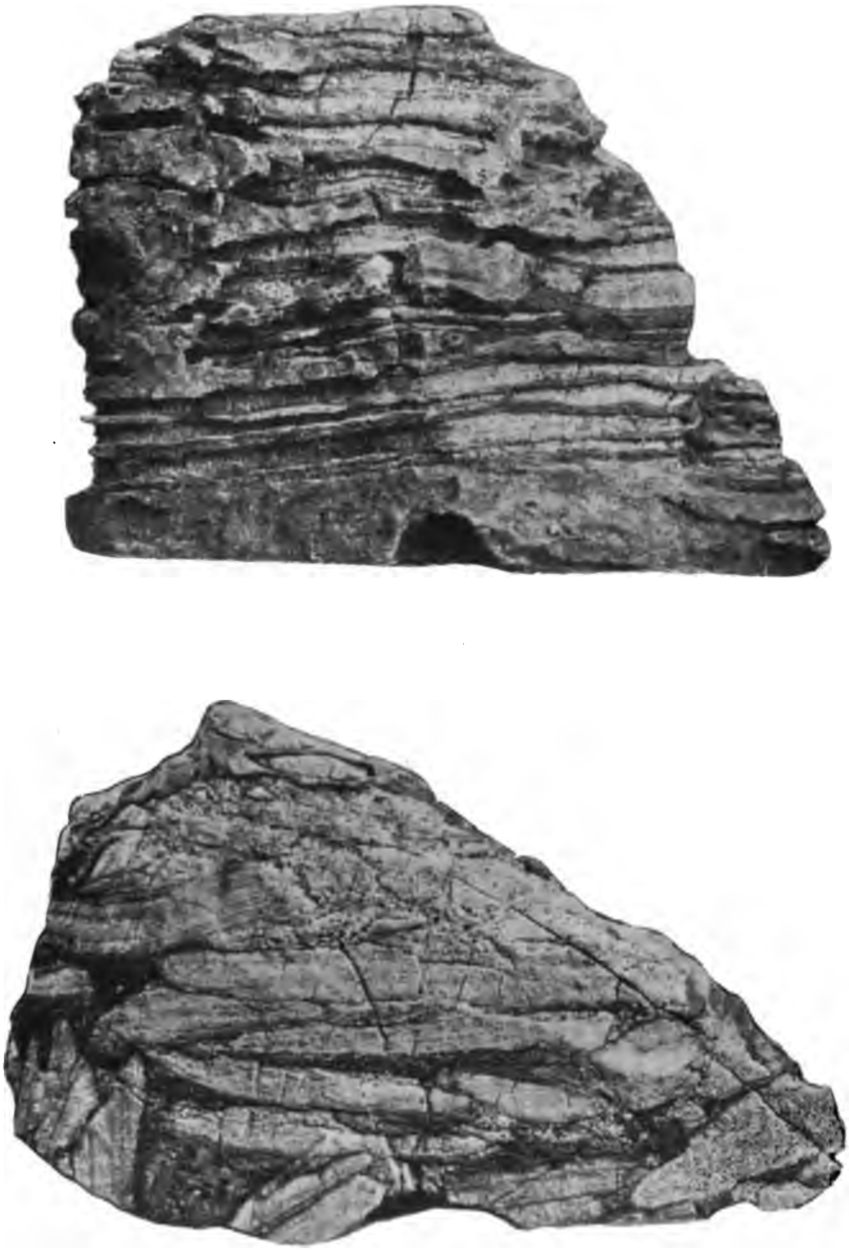
The Cambrian beds are seldom well exposed, and do not form conspicuous outcrops. The peculiar reticulated shales and equally characteristic limestone conglomerates are seen in the stream drift, but the slopes are generally smooth and débris-covered, mostly wooded or grassed, the rocks and disintegration products being frequently hidden beneath débris coming down the slope from porphyry sheets higher up. The more highly altered beds at the base of the series sometimes form low, shelf-like exposures, but they are not a striking feature of the scenery.

Several prospects have been located in the Cambrian areas, mostly on the lower contact of the porphyry sheets with the shaly strata. General observations throughout the State show, however, that valuable ore deposits seldom occur in rocks of this formation, probably because they are not readily traversed or decomposed by ore-bearing solution.

The base of the series was seen only at one point. At Black Butte a basal quartzite 100 feet thick occurs beneath the shale series and the intruded porphyry. The general occurrence of sandy beds in the lower part of the series indicates that these are not far above the lowest beds of the formation. A section of the Cambrian beds made on one of the buttress ridges, extending from near Pekay Peak to Alpine Creek, gives the following sequence and thickness:

Section of Cambrian strata in Alpine Gulch.

Bed.		Feet.
21.	Limestone; thin bedded, blue-gray in color and markedly different in appearance from the beds below	40
20.	Conglomerate with alternating, very thin layers of limestone and indurated shale. Conglomerates of flat beach pebbles from one-sixteenth to one-half of an inch thick and 2 to 3 inches long, cemented by a matrix that is cherty, indurated shale, rarely limy. The pebbles are limestone, and the conglomerate is usually a faint purplish gray in color. It occurs in low outcrops and forms talus of angular, chippy blocks	125
19.	Limestone and shale in alternating, very thin layers. The limestone is thinly bedded and the shales are well indurated. In general, the limestone is light gray and reticulated with bands of shale, which weather with an oily green color on joint surfaces	20
18.	Limestone: not occurring in definite outcrop, but forming débris of angular fragments of bright green to creamy gray; very dense. Porphyry sheet	75
17.	Limestone; compact and dense, with conchoidal fracture; irregular and thinly bedded, pure and without chert or shale, light brown on fresh fracture	3
16.	Shale; hard and laminated, dark greenish gray in color, with occasional concretionary masses	12



SEDIMENTARY ROCK TYPES: CAMBRIAN.

The upper figure is the banded limestone of bed 3 of the Cambrian section; the lower figure is the conglomerate of beds 3 and 7.

Bed.		Feet.
15.	Limestone; finely banded, with shaly layers one-sixteenth to one-half inch thick; fine crystalline, very pale lavender color, varying to pale green on fresh fracture. Has a platy outcrop with greenish weathered surface	5
14.	Shales; finely laminated; color, dark greenish gray; weathering to fine débris, and containing occasional concretionary masses of limestone	25
13.	Limestone; thinly bedded, gray in color	1
12.	Limestone; similar to No. 15	3
11.	Conglomerate, containing pebbles of limestone up to 2 inches in diameter	1
10.	Limestone; banded, showing alternating beds of varying hardness and color	1
9.	Shales; generally soft and weathering into fine, scaly chips of greenish-gray color and resembling bed No. 14	8
8.	Limestone; alternating bands of dove-color and dense limestone and light-brown granular limestone	2
7.	Conglomerate of limestone pebbles; generally rounded, ovoid, varying from dove color to blue-gray, thickly crowded in limestone cement and ranging up to 1 inch in diameter	1
6.	Shales; soft, readily weathering, finely laminated, and recognizable only from débris of scaly chips containing occasional concretionary bodies of limestone, usually oval in shape and but a few inches across. Contains rather rare shell remains	15
5.	Limestone, with reticulated cherty bands, thinly bedded, and in places running into conglomerate for a few inches at a time. The cherty material weathers with a greenish surface, which is brown on the edges, the chert projecting as ribs above the surface of the limestone. The prevailing color is a dove-gray, but the débris appears green from the abundance of the cherty material	25
4.	Limestone; resembling bed No. 3, often changing to a conglomerate composed of thin, flat pebbles of limestone arranged with but little order and breaking with the dove-colored limestone cementing material. These pebbles do not weather out. Some chert is present, but it is hard to distinguish it from the baked shaly material also occurring in the limestone	20
3.	Limestone; usually gray, holding thin laminæ of shaly, cherty material, striping the beds conformably with the bedding. The limestone is dense, compact, and finely crystalline on fresh fracture, and changes near the top of the bed into more shaly strata	50
2.	Shales; somewhat limy, much more so than the beds beneath, but showing the same thin shaly bedding; well indurated, and forming rough, craggy outcrops that stand out prominently above the smooth slopes. This bed is the rock which forms the prominent Cambrian drift seen in Big Chunk and Alpine gulches, and is characteristic of the Cambrian series, as the porphyry does not rest smoothly against the shales, but has broken along them. They are brecciated near the contact, become more limy at the top, and grade into the limestones of bed No. 3	25
1.	Shales with quartz bands. These are the lowest beds of the section and are generally much altered, somewhat brecciated, and very tough from contact metamorphism. No limestone is seen in this part of the section. This series is immediately underlain by a dense porphyry, pale creamy and pink in color, which shows weathered feldspar crystals and quartzes. The dip of these beds is about 35° away from the center of the anticline	20

The Alpine Creek section shows a thickness of 477 feet of beds that are probably all Cambrian. They are composed of shales, of limestone conglomerates, limestones, and the peculiar rocks that are neither of these, yet resemble them all. These latter rocks are the most noticeable and peculiar rocks of the series, and, together with the conglomerates, form its most characteristic rock type. The rocks often resemble conglomerates, for they are an intimate mixture of limestone in flat, oval masses and hard, shaly material that is often green and cherty. Upon fresh fracture these two constituents are not especially distinguishable, but upon the weathered joint planes the harder material stands out in relief as a green network above the gray limestone inclusions, as seen in Pls. LXX and LXXI. These differences in composition appear to be due to original deposition. The greater part of the section just given consists of this kind of rock, which is there called limestone, and which is in places a true conglomerate of varicolored limestone pebbles. A graphic representation of the Cambrian section is given in fig. 34.

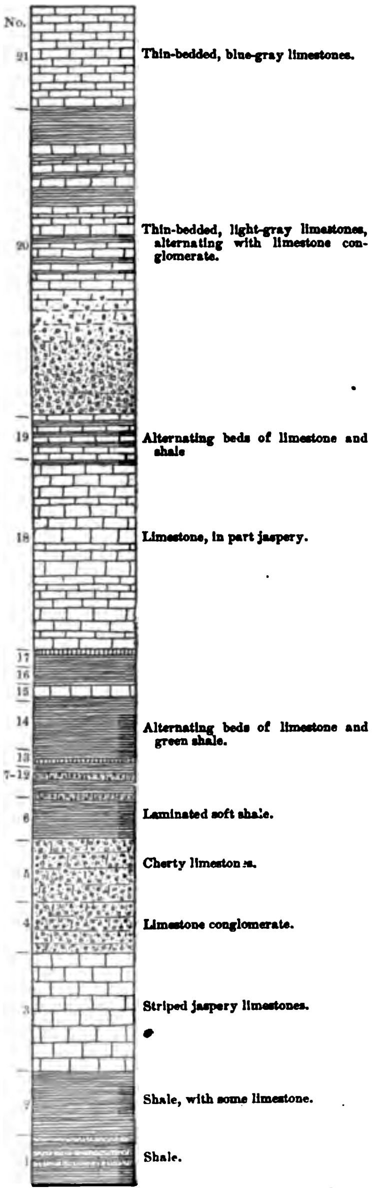
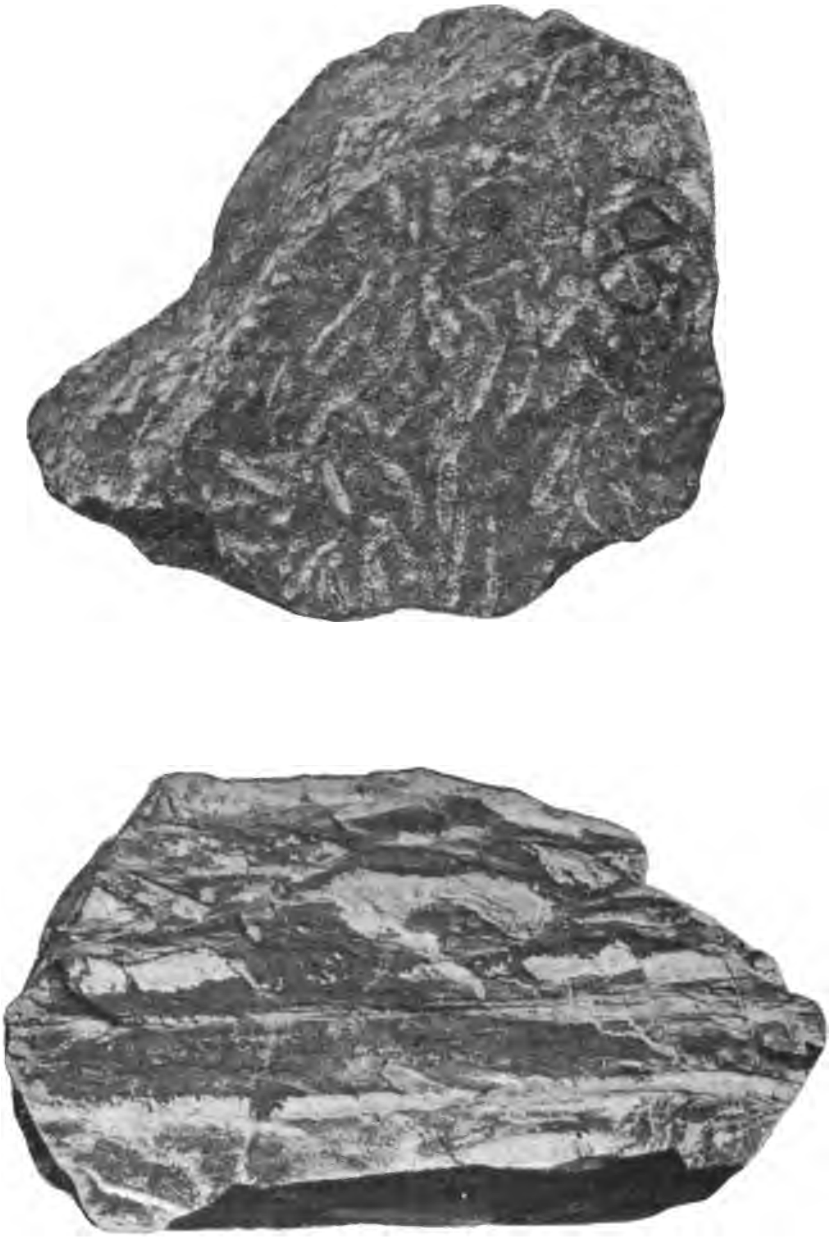

No.
21
Thin-bedded, blue-gray limestones.
20
Thin-bedded, light-gray limestones, alternating with limestone conglomerate.
19
Alternating beds of limestone and shale
18
Limestone, in part jaspery.
17
16
15
14
Alternating beds of limestone and green shale.
13
7-12
6
Laminated soft shale.
5
Cherty limestones.
4
Limestone conglomerate.
3
Striped jaspery limestones.
2
Shale, with some limestone.
1
Shale.

FIG. 34.—Section of bedded rocks of Cambrian age.

Careful search was made for organic remains, but only a few fragmentary fossils were found—a trilobite and a shell resembling Obolella.

SILURO-DEVONIAN ROCKS.

Above the Cambrian beds there is a series of limestone beds differing markedly in appearance from those just described, and as much from the overlying, craggy and massive, heavy-bedded, light-colored limestone of the Carboniferous. The lowest of these intermediate beds are prevailingly dark in color—chocolate-brown or bluish black—and are mostly crystalline limestones, showing a decidedly granular texture upon weathered surfaces. A characteristic feature is a dark-brown rock dashed with cream-colored markings, shown in the upper figure of Pl. LXXI. Above



SEDIMENTARY ROCK TYPES: SILURO-DEVONIAN AND CAMBRIAN LIMESTONE.

The upper figure is the granular, chocolate-colored limestone of the Siluro-Devonian series, with creamy dashes of possibly organic origin; the lower figure is the jaspery or cherty limestone of bed 5 of the Cambrian section.

these dark limestones fissile, shaly, clayey limestones occur. The latter are classed as of Devonian and the former as of Silurian age upon stratigraphic and lithologic grounds, no characteristic fossils having been found in either. The only exposures are those about the rim of the amphitheater of Alpine, New Years, and Burnett creeks, where these beds are rather inconspicuously exposed.

The dark Silurian rocks are distinctly crystalline, weathering with a peculiarly pitted surface, often the result of the weathering out of geode cavities, but in part also due to variations in texture. The dark coloring is due to organic material, and the rocks give forth a strongly fetid odor when struck with a hammer.

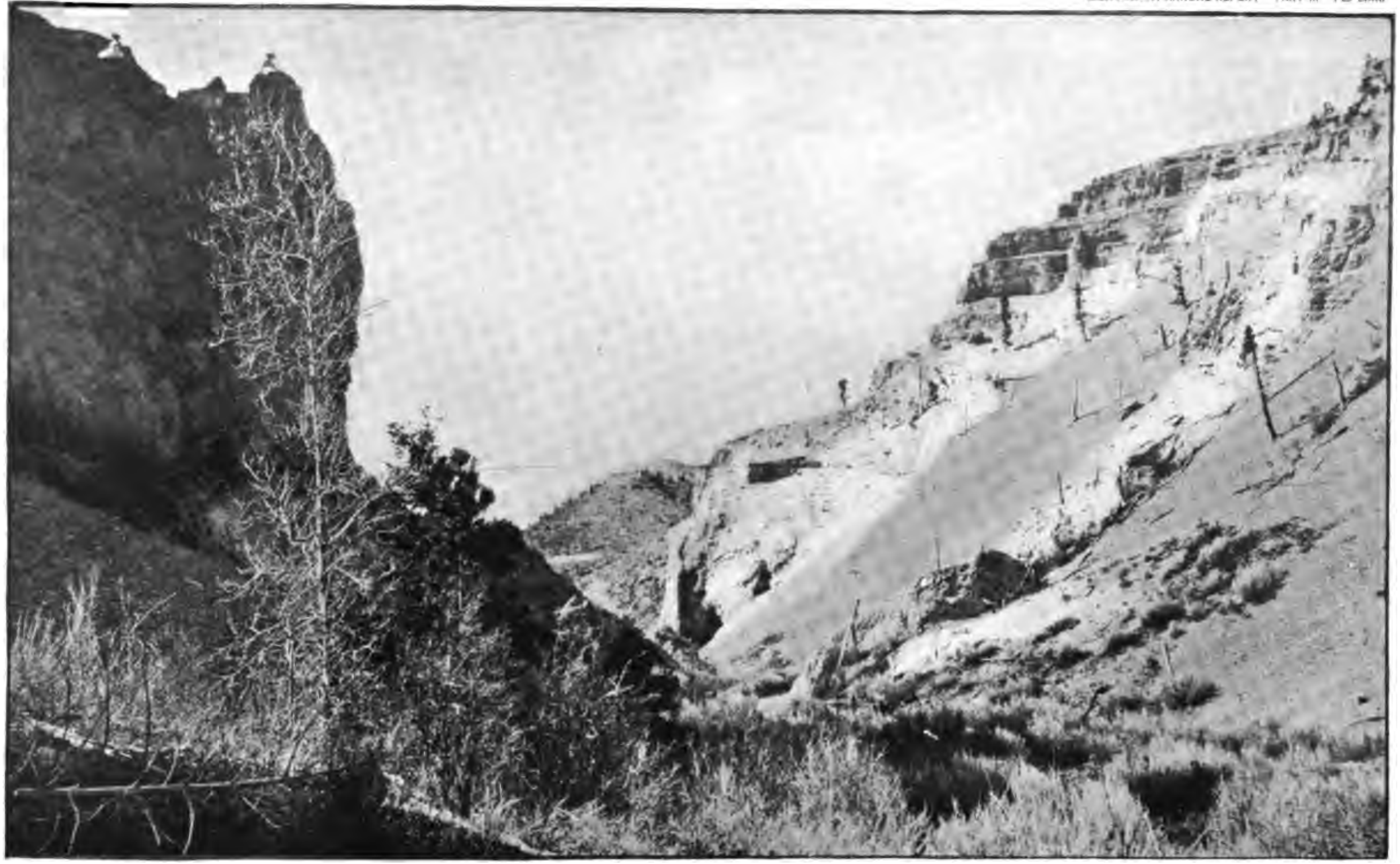
Section of Silurian and Devonian rocks west of Alpine Creek.

	Bed.		Feet.
Carboniferous, Madison formation.	28.	Limestone in alternating beds of brown-gray to blue-gray rock, rudely fissile, and breaking into irregular plates, which form angular débris. The upper 25 feet of this bed is of typical Carboniferous aspect, dark blue-gray in color, and of rudely prismatic fracture, and forms the first of the rough, craggy outcrops which characterize the Carboniferous limestones	65
	27.	Limestone: upper part showing no exposure, but abundant brownish-gray débris; the lower 5 feet is a blue-gray limestone, carrying silicified fossils. This is the lowest bed assigned to the Carboniferous	15
Devonian, Three Forks formation.	26.	Limestone; granular, gray to brownish-gray in color, showing crystalline, crinoid stems, and occasionally corals of Devonian aspect. The rock changes to a cavernous, pink limestone of inconstant nature near the top	26
	25.	Limestone; thinly bedded, breaking into débris of dove-pink or light-gray color that strongly resembles the débris of porphyry	30
	24.	Limestone; light gray, rough weathering, rudely bedded, irregularly crystalline	6
	23.	Shaly limestone, dove-gray to pink in color, and resembling Devonian horizons of Rocky Mountain front	25
	22.	Limestone; pink to cream-colored, dense, and breaking into fine, angular fragments; forms a fissile outcrop	5
	21.	Dark-blue limestone, resembling beds beneath it	6
	20.	Shaly limestone, cream to pink in color, dense, and breaking into small angular fragments	5
	19.	Limestone; light brown, rough weathering, not fissile. This is the lowest bed of what is believed to be the Devonian series	20
Silurian, Jefferson formation.	18.	Limestone; light gray, weathering with granular surface, contains chert nodules, and the outcrop shows a peculiarly pitted surface characteristic of the Silurian horizon throughout the Rocky Mountain area of Montana	12
	17.	Limestone; chocolate-colored with very finely granular surface and fracture, carrying calcite geode cavities, and occasionally brecciated with both fragments and cement of same material. The rock has a fetid odor and a peculiar, rough, weathered surface, and breaks into rounded or subangular pieces	25
	16.	Limestone; light gray, not well bedded, full of calcite strings and bunches, and rather rotten in texture	5

	Bed.		Feet.
Silurian, Jefferson formation.	15.	Limestone; chocolate-colored and dark-gray beds alternating, finely granular, with fetid odor and usually Jefferson aspect	10
	14.	Limestone; dark bluish gray, finely granular, and similar to beds beneath	20
	13.	Limestone; light dove-colored, often blotched with pink, and generally somewhat rotten on weathered surface	7
	12.	Limestone; dark blue-gray, finely granular, showing lamination lines, not splitting with bedding readily, but breaking into prismatic blocks and fragments	25
	11.	Limestone; fissile, fine grained or very finely granular, dark brownish gray in color	3
	10.	Limestone; light gray, rough weathering, resembling conglomerate	10
	9.	Limestone; massively bedded, bluish gray, with pink mottling, and of crystalline texture	5
	8.	Limestone; fissile, almost shaly in outcrop, light dove in color	5
	7.	Limestone; dark bluish gray, and of saccharoidal texture	2
	6.	Limestone; bluish gray, similar to bed No. 25, and including 1 foot of cream-colored limestone that is massive and carries crystal cavities	15
	5.	Interval covered by dove-colored débris from upper beds	10
	4.	Limestone; bluish gray, of Silurian aspect, and carrying minute crinoid stems. The rock breaks into small, angular fragments, is often mottled with a reddish stain, and weathers with a granular surface	6
Cambrian.	3.	Limestone; this is not well exposed, but forms a débris of brick-red and dove-colored granular rocks, which become more shaly at the top	20
	2.	Limestone; thinly bedded, dove colored, weathering with granular surface, resembling sandstone	10
	1.	Conglomerates of purplish color and Cambrian aspect	

CARBONIFEROUS ROCKS.

The massive white limestones which are so prominent a feature of the mountains when seen from the plains and which form the summit cliffs and the walls of stream canyons are of Carboniferous age. The ore deposits of the Giltedge mines occur in these rocks, and the towering walls and pinnacles of the gorge of Maiden Creek, followed by the road to Spotted Horse and Maiden (see Pl. LXXII), are of the same white limestone beds. Their general distribution is shown upon the accompanying geologic map (Pl. LXXV). From the surrounding plains the limestone beds are seen curving about the mountain flanks in great overlapping plates, as shown in Pl. LXXX. These rocks, when present, define quite sharply the mountains from the surrounding level lands, for the limestones resist erosion much better than the overlying shales and sandstones, as shown in Pl. LXXVI. This feature is a common one throughout the eastern border of the Rocky Mountain region of the State, giving rise to the name "mountain limestones," often applied to these beds, and is in strong contrast to



MAIDEN CANYON; CARBONIFEROUS LIMESTONE, THINLY BEDDED.

the phenomena exhibited on the eastern border of the continent, where limestones characterize the lowlands and valleys.

The occurrence of Carboniferous limestones in the Judith Mountains was first observed by Dana and Grinnell,[1] who collected fossils from the beds in 1875, and described the occurrence of "at least 300 to 400 feet" of massive white limestones, the upper layers of which "are white, semi-crystalline, and very profuse in flinty fragments." Owing to the structure and vegetation the exact base of the formation has not been determined in the section measured, but is given in the Siluro-Devonian section previously described. The total thickness of the formation is estimated to be 800 feet. The following section, showing 731 feet of these Carboniferous limestones, was measured along the walls of Maiden Gulch, below the Spotted Horse mine settlement, and extends up to the well-defined Jurassic limestone at the top.

Section of Carboniferous strata exposed in walls of Maiden Gulch, below Spotted Horse.

Bed.		Feet.
21.	Limestone; fissile or shaly, dense and not crystalline, dove-colored; débris fragments showing pinkish and purplish weathering; resembles Jurassic somewhat; conchoidal fracture; at 10 feet from base contains a layer of oolitic limestone	20
20.	Limestone; impure argillaceous and ferruginous, possibly sandy. In places shaly, but mostly breaking into rotten, earthy material that is seldom exposed. The lower 5 feet is bright red at Giltedge. Ocherous yellow is the characteristic color. Forms sag between surface of underlying beds and a spur beyond formed by bed No. 21	40
19.	Limestone; thin bedded, gray, breaking into small flat fragments	5
18.	Limestone; massive, creamy gray, brecciated appearance; forms cliff that is at times overhanging, no stratification lines; contains rather rare occasional chert nodules, generally small, but at times 1 foot in diameter, banded	35
17.	Limestone; fissile, weathering down and breaking into débris slope between cliffs	20
16.	Limestone; forming massive ledges, gray, rudely and heavily bedded, cavernous, with intercalated layers of a brownish limestone having splintery fracture and differing from the rough-weathering surface of the main bed. Forms bold buttresses at the canyon mouth. Carries in places angular fragments of black chert	55
15.	Limestone; thin-bedded, fissile, calcareous shales, in places buff to pink on weathered surface	40
14.	Limestone; series of thick- and thin-bedded limestone with prismatic fracture, gray, varying somewhat in texture and tint, forming steep cliff; full of big corals and other fossils in the thin shaly layers a few inches in thickness	70
13.	Limestone; thin bedded, platy, gray to buff, somewhat impure	5
12.	Limestone; massive, gray, with splintery fracture breaking into prismatic blocks; carries abundant fossils of crystalline calcite. Resembles beds below, as No. 3	100

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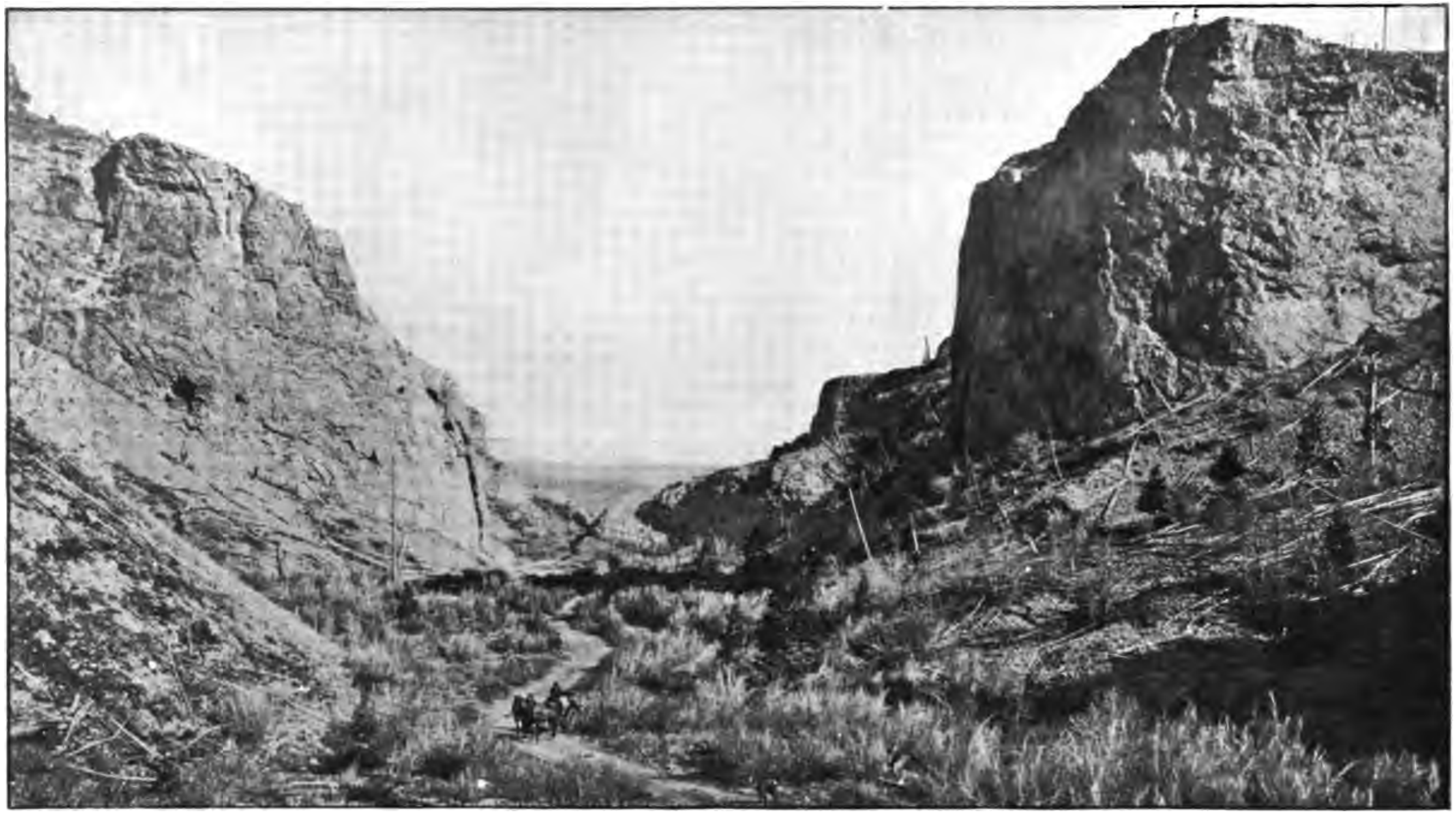
[1] Report of a Reconnaissance from Carroll, Montana Territory, on the Upper Missouri, to the Yellowstone National Park, and Return, made in the Summer of 1875, by William Ludlow. War Department, Washington, 1876, p. 99.

Bed.		Feet.
11.	Limestone; thin bedded, not crystalline, carrying argillaceous material, showing brachiopods and corals which weather out on surface	10
10.	Limestone; heavy bedded, but usually showing no stratification lines to general view; dense, carrying bands of black chert several inches thick, which are conspicuous in outcrops. This limestone is the heavy, massive limestone cliff so prominent in canyon. Cliff is nearly persistent; is much cracked and checked in places with seams filled with calcite. Forms massive buttresses in the canyon at points where side canyons come in and elsewhere; is in general a dove-gray, but weathers in places to a reddish buff (due to lichens) on large surfaces. Outcrops are often rounded. Contains numerous caves that are old water courses	70
9.	Limestone; blue-gray, thin bedded, breaking into angular débris; no good exposures; slightly crystalline	25
8.	Limestone; massive, irregularly bedded, open and cavernous structure, forming round but irregular outcrops, varying considerably in shades of gray in texture, and in purity of material, in places resembling a breccia of a dark color; fragments in buff color cement, this character being rare	45
7.	Limestone; shaly, thin bedded, weathering buff and purplish, changing horizontally to harder, less shaly limestone, showing lamination lines and varying to limestone conglomerate of flat pebbles; seldom well exposed	30
6.	Limestone; thin bedded and platy; cream-color outcrop is in strong contrast to massive beds below; finely crystalline and lacking in chert	25
5.	Limestone; dove-gray, forming second cliff and first persistent one of canyon; heavy-bedded, showing no fine stratification lines; much chert in bands and strata up to 6 inches thick; limestone showing at base round and ovoid chert inclusions of concretionary nature, well banded with concentric layers. Bed No. 4 is well exposed in cliff a rod or two down canyon, where it is seen to be continuous with No. 5, from top of that bed down to top of No. 3, and of same general character throughout. Certain layers are composed mainly of crinoid stems	20
4.	Limestone; thin bedded, but breaking with prismatic fracture; beds not well exposed, but forming slope between two lines of cliffs; fossils very abundant in certain layers, but mostly fragmentary; mainly crinoid stems. Base of second cliff from bottom	60
3.	Limestone; well-defined and thin beds, 1" to 11" thick. Differential weathering has developed overhanging ledges; contains considerable chert, irregularly scattered through rock, seldom forming well-defined layers or nodules. This bed forms first cliff, but it is not a persistent bluff	6
2.	Limestone; finely crystalline, dove-gray, forming massive bed, showing no stratification lines; breaking with prismatic and splintery fracture, and in marked contrast to bed immediately above; contains a few fossil remains, mostly of crystallized calcite	20
1.	Limestone; thin bedded, cream to blue gray, finely crystalline; breaks with splintery and rudely prismatic fracture. These thin-bedded rocks are not well exposed, as they break readily and are covered by grass and abundant slide of splintery fragments from the beds above	50

This section shows only limestones. At the base they are thinly bedded, somewhat darker gray than the higher strata, and weather readily, as illustrated in Pl. LXXII. The conglomerate of bed No. 3 is



MAIDEN CANYON; CARBONIFEROUS LIMESTONE, MASSIVELY BEDDED.

significant of the conditions prevailing during the deposition of the limestone of the earlier beds. The abundance of crinoids and other relatively shallow-water species of fossils is in accord with this evidence, and shows that the limestones are shallow-water deposits.

The limestones of beds Nos. 12 to 14 form a series of retreating cliffs in continuous exposure on the east side of the gulch, seen in Pl. LXXII. The rocks are evidently a part of the great series of massive-weathering Carboniferous formations, but show good bedding planes and weather with masonry-like appearance, due to slower weathering of the harder ledges, 3 to 4 feet thick, which overhang the more shaly beds. At the top of the cliff three or four of these beds weather as steps upon a timbered slope, and are in turn overlain by the heavy bed of massive white limestones that everywhere forms the "gates" or portals of the gorges leading from the mountains, as shown in Pl. LXXIII.

Bed No. 20 is the only one in the section that can be correlated with the Quadrant formation of the Yellowstone Park vicinity or the Yogo formation of the Little Belt range. These formations represent the closing period of Lower Carboniferous time in the Rocky Mountains. In the Judith, bed No. 20 is bright yellow in color, loose textured, and resembles a sandstone. It is very calcareous, shows small black stainings of moss-like form, and weathers into soft, sandy earths. It contains a large amount of insoluble material that appears to be siliceous sand.

.FOSSILS.

Fossils occur at various horizons throughout the section, but none were found in the two uppermost beds. The species are all of Lower Carboniferous types. The fossils collected by Dana in 1875 from the limestone exposures west of the head of Box Elder Creek were identified by Prof. R. P. Whitfield as follows:

1. Crinoidal remains, too indistinct to be identified.
2. Terebratula or Cryptonella.
3. Spirifera (Martinia) lineata Martin.
4. Spirifera centronata Winch.
5. Orthoceras?

Spirifera centronata Winchell was the most abundant and characteristic form observed here.

Fossils were also collected from the Carboniferous rocks at the head of Boyd Creek, identified as follows:

1. Zaphrentis centralis Ev. & Shum.
2. Syringopora mult-attenuata McChes.
3. Stictopora sp.
4. Spirifera centronata Winch.

Fossils collected by myself from the summit of Crystal Peak (bed

No. 18 of section) were identified at my request by Mr. Charles Schuchert, as follows:

Chonetes loganensis H. & W.
Leptæna rhomboidalis Wahl.
Spirifer centronatus Winch.
Orthothetes.

The spirifer is not only the most abundant species in the Judith Mountains, but generally in the Carboniferous rocks of Montana.

The following report of Mr. George H. Girty upon the fossils collected from the Carboniferous horizon of the Judith Mountains shows the specific identifications and character of the fauna from the different localities:

Head of West Fork of Boyd Creek:
  Pleurotomaria sp.
  Murchisonia sp., near M. terebriformis Hall.
  Rhombopora, several species.
  Spirifer centronatus Winchell.
  Seminula humilis, nobis.
  Seminula madisonensis, nobis.
  Seminula immatura ?, nobis.
  Rhynchonella, several species.
  Myalina sp., cf. M. congeneris Walcott.
South side of Crystal Peak, at 5,626 feet:
  Orthothetes inflata White & Whitf.
Maiden Gulch:
  Syringopora pollux, nobis.
  Spirifer centronatus Winchell.

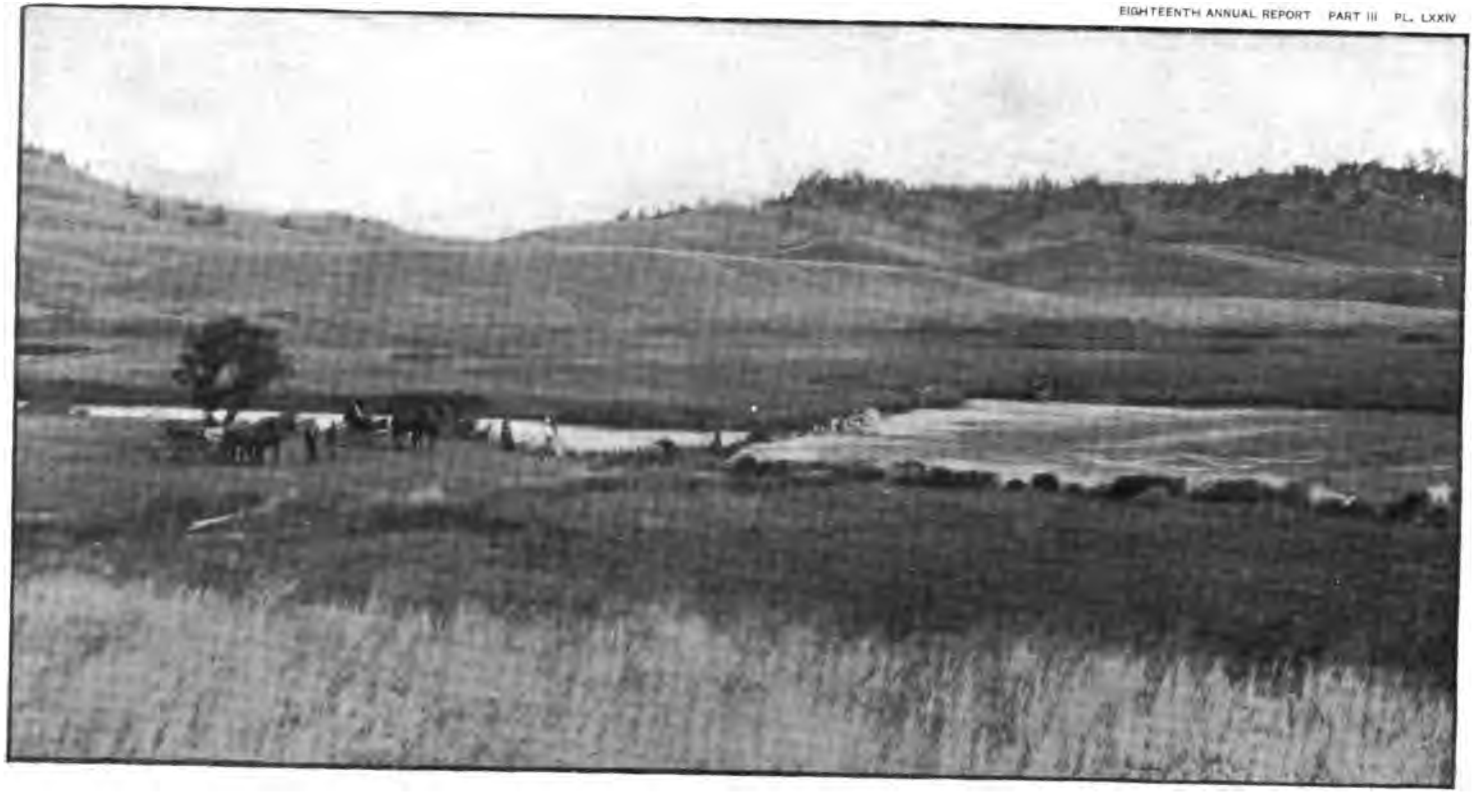
The fossils of these four localities seem to represent a single geological formation, and one showing well-marked affinities with the Madison limestone of the northern Rocky Mountain areas. The faunal resemblance is most marked where the Brachiopoda alone are considered, *Spirifer centronatus*, *S. humilis*, *S. madisonensis*, *S. immatura*, *Orthothetes inflata*, and *Syringopora pollux* being all found in the Madison limestone, where several, notably *Spirifer centronatus* and *Orthothetes inflata* are extremely abundant. Several of these are manuscript names of species described from Yellowstone National Park.

The Judith Mountain localities, however, show a quite different gastropod and pelecypod development. It is a striking fact that in the Yellowstone Park only two specimens, representing two genera of pelecypods, were collected, both of them generically different from *Myalina congeneris* (?), while the abundant, practically the only, gastropod found in the Madison limestone is *Straparollus utahensis*, which has not been found at the Judith Mountains.

The rhynchonellas cited from one locality are very small and immature forms, so that I was not able to identify them. The rhomboporas also, of which several species may be represented, were indeterminable on account of their coarsely silicified condition.

Specimens of Carboniferous limestone from the Spotted Horse mine were examined by Prof. C. E. Beecher, of Yale University, who found the following forms present:

Productus semireticulatus ?
Chonetes sp.
Derbyia sp.
A gastropod, possibly Euomphalus.



WARM SPRING, BELOW MAIDEN.

A specimen from the upper part of the Carboniferous of Maiden Gulch showed a brachiopod, probably Terebratula, possibly Dielasma.

RÉSUMÉ.

Considered as a whole, the Paleozoic rocks of the Judith Mountains present the same sequence of rock types found in the Front Range of the Rocky Mountains. The resemblance is closest to the sections in the Little Belt range in the vicinity of Yogo and Barker. This is to be expected, since they are a part of the series forming the mountain uplift that raised the Little Belt ranges, an anticline that disappears beneath the Cretaceous rocks at Judith Gap and reappears in Big Snowy Mountains, just south of the Judith Mountains. The close accordance of the sections of the Judith Mountains with those of the Rocky Mountains at such distant points as Neihart, Livingston, and the Yellowstone Park is rather remarkable, the general characters of the rocks belonging to each age being the same at these distant localities. The sections show shallow seas throughout this region at the beginning of the Middle Cambrian, succeeded by deeper waters in which limestones of varying composition were deposited until the close of the Lower Carboniferous epoch. During this long lapse of time deposition appears to have been conformable, but periods of shallowing are represented by the arenaceous limestones of the Silurian. The shales and coal of the Devonian of Three Forks have no representation here.[1] The rocks show that these oscillations were not so evident here as farther westward. The Carboniferous of the Judith region ends with massive and pure limestones. The shallow-water beds, with impoverished fauna, found on the east slope of the Little Belt, are not represented here.

The entire Paleozoic section is of much less thickness than it is farther westward. As the base of the Cambrian is not seen, a strict comparison of those terranes can not be made, but the Silurian, Devonian, and Carboniferous are not so thick as they are farther westward. This is in accordance with previous observations, which show a thickening of the Paleozoic series from the eastern flanks of the Rockies westward.

MESOZOIC ROCKS.

The strata of this age form the plains country about the mountains, and also the lower slopes and hills about the intrusive masses of the northern part of the area. In the southern part of the mountain group these rocks cover but small areas and are found in concentric exposures about the mountain flanks. The rocks are all soft and readily eroded, so that they usually form gentle slopes, in marked contrast to the bolder forms due to the more resistant rocks of other ages or types. The most prominent feature of the series is a massive bed of yellowish sandstone, forming a bold hill occurring at intervals as an encircling ridge about the mountains, whose character is seen in Pl. LXXX.

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[1] The Paleozoic section in the vicinity of Three Forks, Montana: Bull. U. S. Geol. Survey No. 110, 1893, p. 30.

The Jurassic series has no economic importance so far as known. The detailed section given in this chapter is, however, of practical value, as it is often necessary to know the character and thickness of the beds intervening between the massive white Carboniferous limestones, so generally exposed, and the coal seam that occurs in the Cretaceous. The measured sections show a total thickness of 380 feet of beds in this interval.

The Cretaceous rocks are essentially the rocks of the plains. Exposures do occur in the elevated parts of the region, notably between Maiden and Judith peaks, in Ross Pass, and about the headwaters of Armell Creek, where they have been included between intrusive bodies of igneous rock. Where the rocks occur in the well-watered mountain tract they are very generally concealed by soil and vegetation, and good exposures are uncommon. In the foothills and plains the semiarid climate favors good exposures, except where the thin veneer of drift on gradation terraces conceals the beds. The economic importance of the Cretaceous rests upon the occurrence of the coal seam and associated fire-clays, together with the usefulness of the easily dressed sandstones for building stones.

JURASSIC ROCKS.

Overlying the massive, heavily bedded limestones, which are the most prominent sedimentary rocks of the Judith Mountains, there is a series of thin-bedded strata which generally form somewhat gentle slopes at the base of the mountains. The lowest beds are of dark-gray limestone, thin bedded, and carrying fossils 10 to 15 feet above the base. There is frequently a sag or ravine between these limestones and the Carboniferous rocks, due to the weathering of the yellow, calcareous bed at the top of that series.

Above the dark limestones that form the base of the Jurassic the beds become more shaly and argillaceous, and near the top have intercalated beds of sandy material. The total thickness is 184 feet. Good exposures occur at numerous places about the mountain front. Below Maiden the lower limestones form ledges near the road, and an unpromising prospect pit is sunk in the rocks. These Jurassic beds often form mammillary hillocks 10 to 20 feet in height in the interval between the white limestone slopes and the ridges carrying the coal beds. The beds are well exposed near Giltedge, where the following section of the series was measured:

Section of Jura-Cretaceous beds exposed on ridge between Giltedge and Virgin creeks, near Giltedge.

	Bed.		Feet.
Dakota.	39.	Sandstones, with interbedded, red earthy shales, forming bright-red soils	400
	38.	Quartzite, resembling gray limestone; dense and knotty in texture	4
	37.	Sandstone like that below, the lower 2 feet of the bed being a dense, buff-colored quartzite, the upper part of the bed being shaly	15
	36.	Red soils, which are not exposed	20
	35.	Sandstone; granular, gray in color, varying to buff	6
	34.	No exposure, but slope covered with red soil	15
	33.	Quartzite, dense, resembling limestone in weathering and appearance	5
	32.	Shales, with interbedded thin layers of dark-gray sandstone	30
Kootanie.	31.	Sandstone, coarse, gray, varying considerably in texture and weathering pinkish or red on the edges of the débris; a normal sandstone (100 feet horizontally)	30
	30.	Gray shale	6
	29.	Coal, soft, crumbly fuel; seam opened by short incline	(*a*)
	28.	No exposure, but probably sandy shales	50
	27.	Sandstone, coarse, gray, gritty, and with gray argillaceous lignite-colored band 8 inches in thickness in center, in which black fossil wood was found. (Sharp upraise above this ledge and limestone bench below)	12
	26.	Shale, gray, argillaceous, breaking in small angular bits	5
	25.	No exposure; débris of sandy shale	45
	24.	Limestone, argillaceous and impure, dove-colored and much crackled. This bed weathers as a well-exposed ledge and forms bench	12
	23.	Shales, sandy, and with fine, round, pebbly fragments	12
	22.	Sandstone, gray and shaly	18
	21.	Sandstone, saccharoidal, and like that beneath	10
	20.	No exposure	5
	19.	Sandstone, variable in color from gray to yellow, weathering pink	7
	18.	Sandstone, grading into a dark-gray shale at top	15
	17.	Sandstone, white to light gray or pink, and granular	1
	16.	No exposure	5
Jurassic, Ellis formation.	15.	Ellis sandstone; variable—buff, platy sand rock; pink blotched at base, with occasional shells; cross bedded, purple-brown outcrop. It is at top a limestone full of white and black quartz sand grains, and forms a dark-brown ledge	12
	14.	No exposure, but débris of sandstone	60
	13.	Marly shales and limestones, dove-colored, carrying fossils noted in following pages; seldom exposed; Gryphæa most abundant here	30
	12.	Irregularly platy, earthy-brown gray limestone, carrying shell remains Gryphæa, Ostrea; weathering dark brown; rarely granular	6

a 17 inches.

	Bed.		Feet.
Jurassic, Ellis formation.	11.	Sandy limestone like that above, but irregularly bedded and resembling sandstone; granular and saccharoidal in texture; carries shell fragments	4
	10.	Rough-weathering limestone, fine grained, even bedded, and fissile; carries fossils	5
	9.	Shaly beds which are seldom exposed and carry oolitic limestone. Granular or sandy limestone of drab color	15
	8.	Shaly, argillaceous, impure limestones, dove-colored, weathering buff on joint faces, and of typical Jurassic aspect	5
	7.	No exposure	25
	6.	Limestone, blue to gray in color, hard in texture, and carrying ostreas in 3-foot to 5-foot beds, separated by thinner platy beds	12
	5.	Limestone, dark gray, laminated, and shaly	10
Carboniferous.	4.	Porphyry sheet of Giltedge mine	50
	3.	Limestone, impure, thinly bedded, buff colored, with saffron-yellow outcrop; soft and with earthy outcrop; former bed No. 20 of Carboniferous section, Maiden Gulch	43
	2.	Thinly bedded limestone, impure, platy, dove-colored, dense, weathering buff	25
	1.	Massive Carboniferous limestone, outcropping at ore bin of Giltedge mines, east side of creek	

The rocks of the Ellis formation are not conspicuous, and are frequently concealed by soil and vegetation. They can, however, always be found, if searched for, above the white mountain limestones.

FOSSILS.

The formation is characterized by marine fossils of well-marked Jurassic types. The following species were identified for me by Mr. T. W. Stanton from collections made in 1894 in the vicinity of Giltedge:

Pentacrinus asteriscus M. & H.
Ostrea strigilecula White.
Gryphæa calceola var. nebrascensis M. & H.
Modiola subimbricata Meek.
Cucullæa haguei Meek.
Pleuromya subcompressa Meek.

Collections from numerous other localities yielded similar species. Although collections were made from different horizons of the series, the species proved the same throughout, so that the fossil evidence indicates that the beds form but one series. The following identifications were made by Mr. Stanton:

Giltedge mine:
  Gryphæa calceola var. nebrascensis M. & H.
  Modiola subimbricata Meek.
  Pleuromya subcompressa Meek.
  Natica sp.

The foregoing species indicate the fossiliferous zone of the Yellowstone Park Jurassic section.

Maiden; by roadside below town:
  Cyprina? Numerous small casts and impressions, with a few indeterminate casts of a small gastropod. The material is too imperfect to fix the horizon.
Warm Spring anticline; middle part:
  Ostrea strigilecula White.
  Ostrea. A large species represented by fragments.
Top of Warm Spring anticline (Jurassic (?) limestone):
  Cyprina? sp. Casts. Probably same as fossils of limestone found near road below Maiden.
Ridge west of Lookout Peak; head of Edwards Gulch:
  Ostrea or Gryphæa. Indeterminate fragments.
Foothills southwest of Ross Pass:
  Ostrea. Fragments of a large species, probably the Jurassic O. engelmanni.
Head of east fork of Pete Creek, on west side Ross Pass:
  Gryphæa calceola var. nebrascensis M. & H.
  Mytilus whitei Whitfield. Jurassic.
Upper Ruby Gulch, head of Boyd Creek:
  Ostrea strigilecula White? Numerous fragments. Jurassic.
Head of Boyd Creek:
  Camptonectes pertenuistriatus H. & W. Jurassic.
Ruby Gulch, head of Boyd Creek. Last bed faulted against Cretaceous:
  Ostrea strigilecula White? Numerous fragments. Jurassic.
Boyd Creek (Ruby Gulch):
  Ostrea strigilecula White.
  Camptonectes pertenuistriatus H. & W. Jurassic.

The rocks of all of the localities represented are apparently of Jurassic age, though in several cases the paleontologic evidence is too meager for positive correlation. The fossils indicate close relationship with the Jurassic of Yellowstone Park, and the two fossiliferous horizons recognized in the Jurassic seem to be both represented in the Judith Mountains.

The beds of Jurassic age show rapid shallowing of the water in this area of deposit. The earlier beds represented are limestones, which are impure and fissile, unlike the pure and massively bedded limestone of the Carboniferous. There is a gradual change in the beds, which are essentially shore deposits; they become more and more argillaceous, with oolites and the appearance of quartz sand, until sandy beds alternate with the impure limestones, succeeded by a 12-foot stratum of cross-bedded sandstone, at times limy, containing marine Jurassic shells in a fragmentary condition—a beach deposit where the shells were broken by wave action. This bed, whose character proves the same wherever it has been recognized, is taken as the top of the Ellis formation. No unconformity between it and the overlying bed has been recognized either here or elsewhere in the Rocky

Mountain region, but the succeeding sediments are of different character and are separated and grouped with the shale and coal seam above, which carry Lower Cretaceous (Kootanie) fossils. This assumes that a thickness of 197 feet of beds, mostly sandstone, in which no fossils have been recognized, are Cretaceous. It is possible they may be equivalent to the Upper Jurassic (Morrison formation) recognized in Colorado, a formation whose equivalent has not yet been found in Montana.

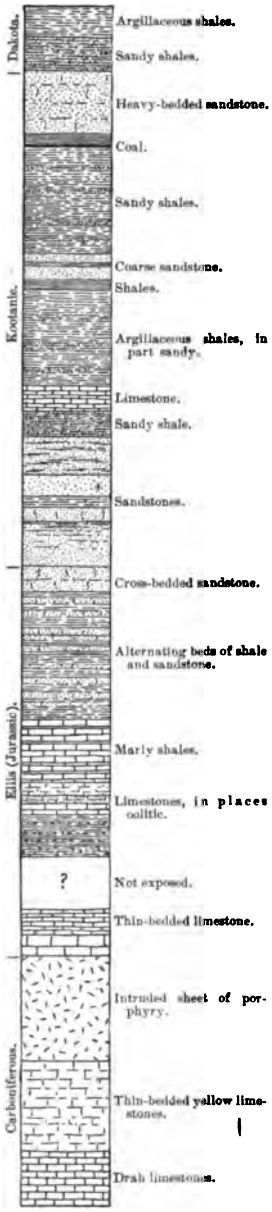


FIG. 35.—Section of Mesozoic rocks of Judith Mountains.

LOWER CRETACEOUS=KOOTANIE.

Throughout the Judith region, occurring generally at the outer base of the mountains a short distance from the foot of the slope, there is a series of light-colored sandstones with brick-red and carmine clays and a workable seam of coal. This series of beds overlies the Jurassic series and carries fossil plant remains in the shales associated with the coal seam, which are of Lower Cretaceous age. It is therefore assigned to the Kootanie horizon, a formation named from its occurrence in the region of that name in Canada. The character of the formation and the alternation of arenaceous and argillaceous beds are illustrated in the section last given, which is typical of the Judith region generally.

The delimitation of the formation is unsatisfactory. The lower limit is defined by the occurrence of Jurassic fossils; the uppermost is entirely arbitrary. No fossils are found in the interval between the coal seam and the marine Jurassic sediments—a thickness of 197 feet of strata which may perhaps represent the equivalent of the fresh-water Jurassic of Colorado.

FOSSILS.

The only fossils found in the formation occur in the clay-shales above the coal seam. Collections made from this bed at Giltedge coal mines in 1894 yielded a number of interesting species, the determinations having been made by Professor Fontaine, who regards them as Kootanie. His preliminary report upon these fossils, embodied in a letter to Prof. L. F. Ward, is as follows:

The plants collected by Mr. Weed from the new localities in Montana constitute a flora different from any known to me. A careful study of the plant remains sent gives the following results:

The plants have suffered some from drifting and maceration, but the shale in which they occur takes such sharp imprints that any parts which retain their character show it very distinctly in the imprints. Considering that the number of specimens is so small, they show a surprisingly large number of new plants of great interest, and I think that if careful collections are made from these localities much light will be gained concerning the Mesozoic flora. The forms made out are these:

1. A fine Zamites, which I think is new. It belongs to that group of Zamites in which occur Dawson's *Z. montana*, and Heer's *Z. brevipennis*, *Z. borealis*, and others that are so characteristic of the Lower Cretaceous. It might be called *Z. weedii.*

2. A smaller Zamites of the same type, which I think is certainly different from the preceding. It is a good deal like Dawson's *Z. montana*, but is, I think, distinct from it. It is exactly like the Zamites which he does not name but figures in his paper On the Mesozoic Floras of the Rocky Mountain Region of Canada, Pl. I, fig. 4.

3. A beautiful and very distinct little fern of the well-marked Acrostichites types so characteristic of the Richmond coal field group, but a new species. It is very different from any Kootanie species known to me. It is a good deal like *Pecopteris geinitzii* Dunk., as figured by Schenk on Pl. VIII, fig. 2, in his Wealden Flora. It is possibly near enough to be a variety of this.

4. These are fragments that agree well with *Angiopteridium strictinerve* of the Potomac.

5. Impressions of stems that in size, etc., agree well with *Equisetum lyelli*, but are without sheaths. Some scattered portions of sheaths not attached to stems are exactly like the sheaths of the same Equisetum, so it is pretty certain that *Equisetum lyelli* is present.

6. There is another and larger Equisetum present that is probably a new species. It is always macerated, and never shows sheaths and leaves attached to the stem preserved well enough to indicate the character of this plant. Its width seems to be 1½–2^{cm} and it is larger than any of the Equiseta of the Lower Cretaceous known to me, except, perhaps, the plant from the Grenschichten, which was named by Schenk *Calamites phillipsii*, and by Schimper *Equisetum phillipsii.* As this also shows no leaves and very imperfect sheaths, the two can not be compared. The dimensions of this Montana Equisetum are more like those of the Equiseta of the Jurassic. There is one imprint of this plant that shows at the summit of a node a number of long apparent leaves and with a midrib, which looks exactly like the leaves of Phyllotheca. My first inspection of this and the presence of rosettes on the stems, which are more common on Phyllotheca than Equisetum, led me to think that this plant is certainly a Phyllotheca. This and the fact that many of the other forms had not been found, as it seemed, in the Lower Cretaceous, led me to think that these strata containing them may be Jurassic. A further careful inspection of all the specimens of the plant in the collection makes me think that it is a new Equisetum, and that the resemblance, in one specimen, to Phyllotheca is due to a peculiar mode of accidental uplifting of the sheaths. Better material is much to be desired. The plant may provisionally be called *Equisetum montanense.*

7. There is a poorly preserved imprint of a fine fern, with all the character of a Thinnfeldia, that is something like one of the forms of the Potomac *Thinnfeldia variabilis*, and very much like Heer's *Dicksonia longifolia* from the Jurassic of east Siberia. More and better material would probably show that it is a new species which might be called in that case *T. montanensis.*

8. There is a pretty stout twig covered with numerous thread-like leaves that is much like *Laricopsis longifolia* of the Virginia Potomac. More specimens are needed to make out its true character.

Besides these, there seemed to be a species of fern that occurs in fragments too small and too poorly preserved for its character to be made out. One specimen is a good deal like the Potomac *Thyrsopteris elliptica*.

As stated, I think that these localities ought to be collected from. There is every indication that they will yield a large number of new plants which will add much to our knowledge of the Lower Cretaceous flora. The facies of the flora seems different from that of the Kootanie and the Great Falls coal group, owing to the large proportion of new forms, but my last study convinces me that its age is Lower Cretaceous and not Jurassic.

UPPER CRETACEOUS ROCKS.

DAKOTA GROUP.

Overlying the coal seam and its associated sandstones and shales is the series of sandstone and dark-gray and red clay-shales which is assigned to the Dakota. The beds are capped by the black marine shale of the Benton. A thickness of 500 feet of strata is assigned to rocks of this age in the Judith section. The section already given shows the character and sequence of beds constituting the formation.

The two formations, Kootanie and Dakota, are both characterized by open and porous sandstones inclosed between Jurassic shales below and Benton shales above, and outcrop about the base of the mountain. These horizons are the water carriers, and, passing beneath the gently inclined strata of the plains, are water reservoirs available for artesian wells. The lower beds of the following section are classed as Dakota.

BENTON FORMATION.

The leaden-gray and black carbonaceous shales of this formation underlie the terrace lands about the mountains, and appear involved in the folds about the intrusion of the northern peaks. The strata carrying intercalated beds of sandstone are characterized by marine fossils. Where these rocks outcrop they yield readily to erosion and form bad lands, but about the mountain flanks they are protected by a veneer of drift and soil, and within the mountains they do not erode in this way. The shales are essentially argillaceous and are of no economic use whatever. The upper part of the following section in Ross Pass, begun where the creek crosses the road the second time, is referred to this group.

Section of Cretaceous in Ross Pass, south side.

Bed.		Feet.
22.	Sandstones, argillaceous, similar to No. 21, passing into thin sandy shales at top, which form large bench and highest exposure seen on this side of the mountains	35
21.	Ash bed of a chocolate-brown color, undoubtedly a volcanic tuff, much altered and with gypsum layers; recalls tuffs of the Highwood Mountains; shows lamination and cross bedding, so was laid down in water; contains fossil bones	1

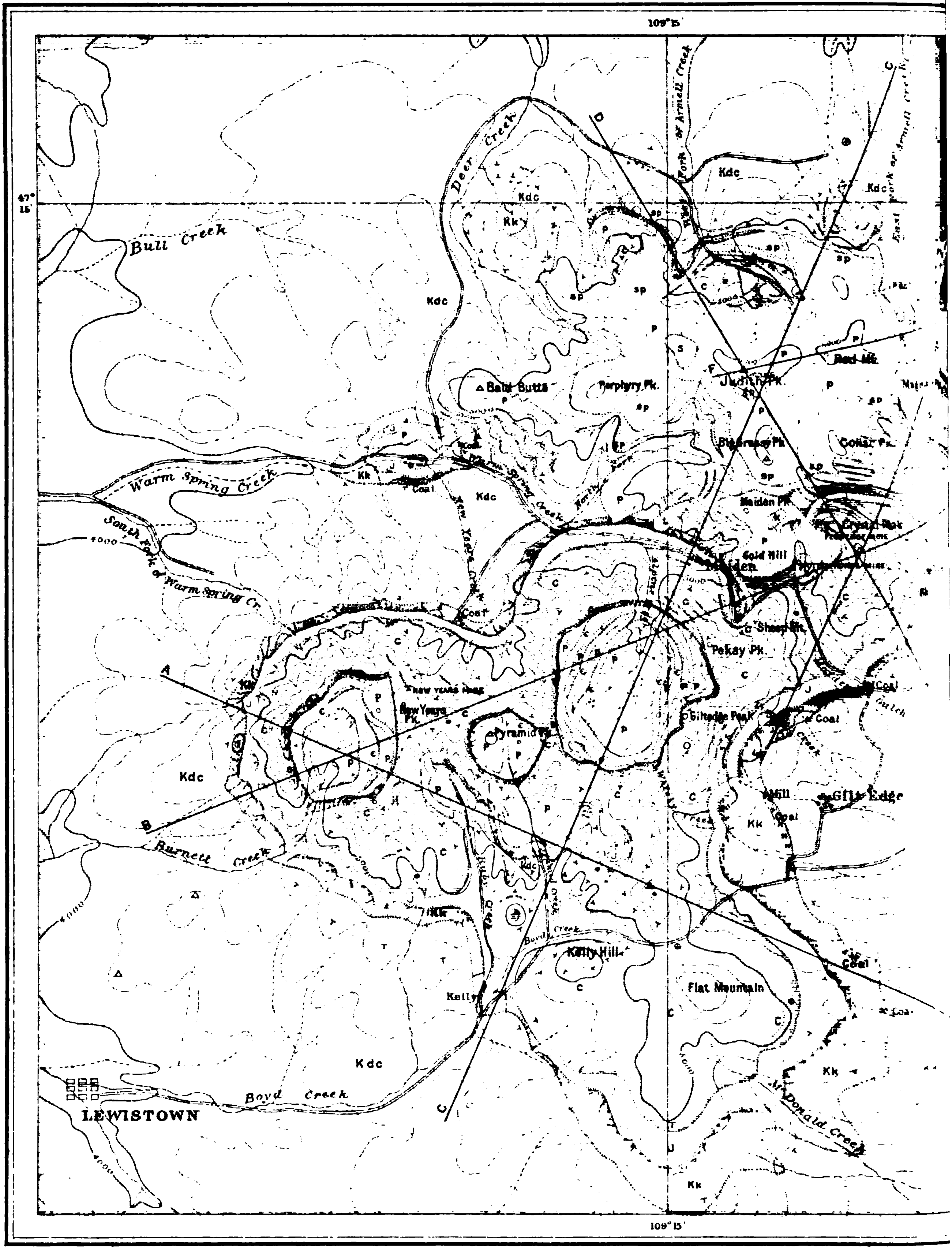
Bed.		Feet.
20.	Sandstone, thinly bedded, fissile, fine, even grain, sugary feel; gray color and shaly character; contains fish scales	10
19.	Shale, black, outcrop broken down and forming steep slope covered with plates of sandstone bed above it	30
18.	Sandstone, mostly broken down, the débris weathering to a brick color; on fresh fracture pale yellowish gray; rather fine, even grain; outcrop broken down	10
17.	Shales, soft, black, scaly; like Nos. 9 and 14	15
16.	Shales, thinly fissile, gray; weathering into tiles one-fourth inch thick, which lie scattered about the slopes and are sometimes pale brown, sometimes bright dove-gray, somewhat sandy, weathering rust-brown on joint faces, with very perfect lamination planes of parting; often somewhat indurated, so that the tiles do not break easily, and pass into a brown, thicker, tougher variety, more like sandstone, that forms top of little bench	10
15.	Same as No. 14, without layers of iron ore	40
14.	Black shales, interspersed with layers a few inches thick of tough iron ore (hematite?) that is black and burnt-looking on surface and breaks into conchoidal chipped pebbles and small but heavy blocks, lying about on surface of soft, weathered shale. There are also occasional drab-brown sandy layers an inch or so thick	25
13.	Sandstone, fissile, in layers 3 inches thick, alternating with bands 5 inches thick, which are very fissile, weather more easily and retreat, leaving others projecting; color, gray; grain very fine and rock argillaceous; weathers on cracks and joints with a brown iron stain; contains what appears to be a very regular mud cracking; forms top of little bench	5
12.	Interval of shale; soil covered with drift from above	40
11.	Shales like No. 9, somewhat indurated at top by what is supposed to be an intruded sheet of porphyry which is thin and broken down	10
10.	Sandstone very fissile, gray, of rather sugary feel, not much indurated, somewhat cross bedded; on slope breaks into small pieces and disintegrates on top to a gray, sandy soil; weathers into extremely large, even, and thin plates	4
9.	Black shales, somewhat indurated at bottom by sheet of tinguaite shales, weathering into fine, black scales, and showing black, side-bank exposures in the drainages. Intercalated every few inches are thin layers of brown, iron-stained bands only an inch or two thick; while the shales are very fine and soft, these are tougher and more indurated and break into little chips an inch or so square, which cover the soil slopes with their brown fragments; occasionally there are flat, lenticular or rounded masses in the black shales. No fossils were seen in them. These black shales recall those of Arrow Creek and Missouri River	60
	Tinguaite, intruded sheet	15
8.	Sandstone, olive-brown, weathering dark umber-brown. Fissile, somewhat indurated and quartzite-like; forms curved smooth surfaces where weathered; shows very fine thin lamination planes and is somewhat cross-bedded, of a fine grain; forms a marked overhanging ledge and is top of second bench in valley; shows what may be worm tracks or casts; has thin fissile layers and others 5 inches thick; softer, thinner layers weather back, thicker overhang; all show the fine laminæ. This rock in large plates is strewn all over the flats below and does not crumble like No. 4 in weathering, but makes characteristic brown soil. It forms bench with wooded outcrop	35

Bed.		Feet.
7.	No exposure; gray-brown soil with thin, chippy, brown shaly fragments, largely also with chips of sandstone from ledge above	10
6.	Drab-colored sandstone, thin, platy, with rough feel and loose texture, and cross bedding	1
5.	No exposure, but a brownish-gray crumbly soil filled with small fragments of a brown, indurated shale; slope covered with plates from ledge above	50
4.	Sandstone, thinly fissile, showing cross-bedding plates about 1 inch thick; has a sugary texture, weathers buff and pink, and changes at the top to a loose-textured variety of a gray color; forms top of first bench; shows ripple marks; recalls sandstone over the coal in character	38
3.	No exposure; soil of a gray sandy character; débris from ledge above	5
2.	No exposure; soil clay, of a reddish color	25
1.	No exposure; soil of a black color; appears débris of a black shale	40

The section is necessarily imperfect from lack of good exposures and the necessity of walking down the backs of the little benches and changing to start anew. It starts necessarily at an unknown point, but certainly low down in Cretaceous and probably near top of Kootanie. The dip is there 15° to 20°.

Whenever a change was made in the section the succession was hunted up and overlaps were made as well as possible, and certain parts were repeated in several places to make sure no slips had taken place. It is believed, therefore, that the thickness given is correct, while the upper part of the section beginning with the black shales is fairly accurate. The porphyry sheet mentioned in bed No. 11 seemed, on later investigation, to be merely scattered talus; if really a sheet, its thickness is inconsiderable.

U.S. GEOLOGICAL SURVEY.



Triangulation and Topography by the
Northern Transcontinental Survey

GEOLOGIC AND TOPOGRAPHIC MAP OF JU

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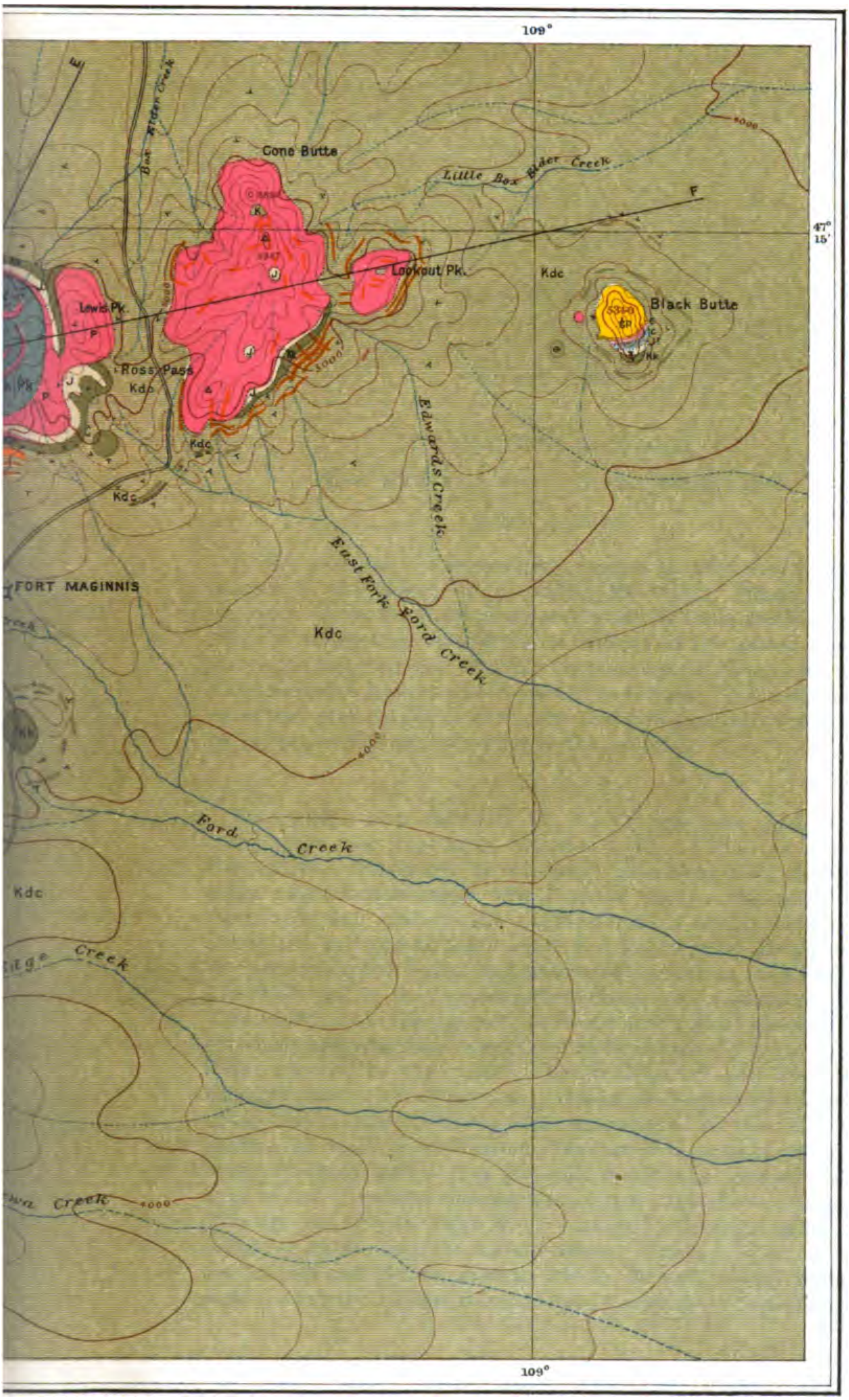


LEGEND

SEDIMENTARY ROCKS

Cretaceous

Kdc

BENTON FORMATION
(black shales and sandstones)
DAKOTA FORMATION
(red clays and sandstones)

■

KOOTANIE FORMATION
(shales, sandstones and coal.)

Jurassic

J

Shales, thinly bedded limestones and sandstones.

Carboniferous

■

Massive bedded limestones.

Silurian and Devonian

■

Thinly bedded limestones.

Cambrian

€

Conglomeratic limey shales and thinly bedded limestones.

IGNEOUS ROCKS

P
SP

Acidic porphyries of the laccolithic masses and intrusives.

ǵp

Granite porphyry

S

Syenite

p

Acidic porphyries in intruded sheets.

t

Phonolite (tinguaite) and phonolitic porphyry in dikes and sheets.

MOUNTAINS AND VICINITY

Geology by Walter Harvey Weed
and Louis V. Pirsson

4 6 Miles

CHAPTER IV.

By L. V. PIRSSON.

DESCRIPTIVE GEOLOGY.

THE WESTERN PART OF THE MOUNTAINS.

INTRODUCTORY.

In this and the two succeeding chapters is presented a detailed account of the geology of the Judith Mountains. Since, with the exception of the brief reconnaissance made by Dana and Grinnell in 1875, in which they crossed the mountains at two points during a march through the region, the country is geologically a terra incognita, this description is given with considerable fullness, the intention being to embody such details as will render the report valuable for local use by laymen as well as interesting to the geologist.

THE GEOLOGIC MAP.

The geologic map shown in Pl. LXXV has been made on the topographic base, previously mentioned (Pl. LXIX). In mapping, the horizons determined by Mr. Weed have been used. The Cambrian conglomeratic shales form horizons easily recognized by their topography and outcrops; the Carboniferous is readily delimited by aid of the outcrops of the massive bed No. 18, near the top, which so commonly forms ledges and gateways throughout the mountains. The fossil bed in the Jurassic, which lies a short distance under the Ellis sandstone at the top, is to be found nearly everywhere; it is an extremely characteristic horizon, and by its aid the top of the Jurassic formation may be determined. The position of these beds, which usually furnish distinct outcrops in relation to the prominent outcrops of the heavy sandstone that is taken as the top of the Kootanie series, enables the ready discrimination of the latter in spite of the lack of other exposures; and as it is the series which is of economic importance, in that it contains the coal of the district, it is shown on the map. This heavy sandstone, which is so prominent in the foothills, has been called for convenience the coal sandstone. The lack of exposures of the Dakota and Benton groups, due to the soft, clayey nature of their shale beds, renders it impossible to map these formations and delimit them without an expenditure of time which would not be warranted by the results to be obtained. The presence of these beds, wherever they are clearly recognizable, is mentioned in the succeeding chapters. Two months of field work have been given to the mapping and study of the district.

The topographic map (Pl. LXIX, p. 446), drawn for reproduction on a smaller scale than that on which it is now given, does not show the topographic detail which would assist in expressing geologic structure, but that the structure is fairly well expressed on the map will be shown in the following pages.

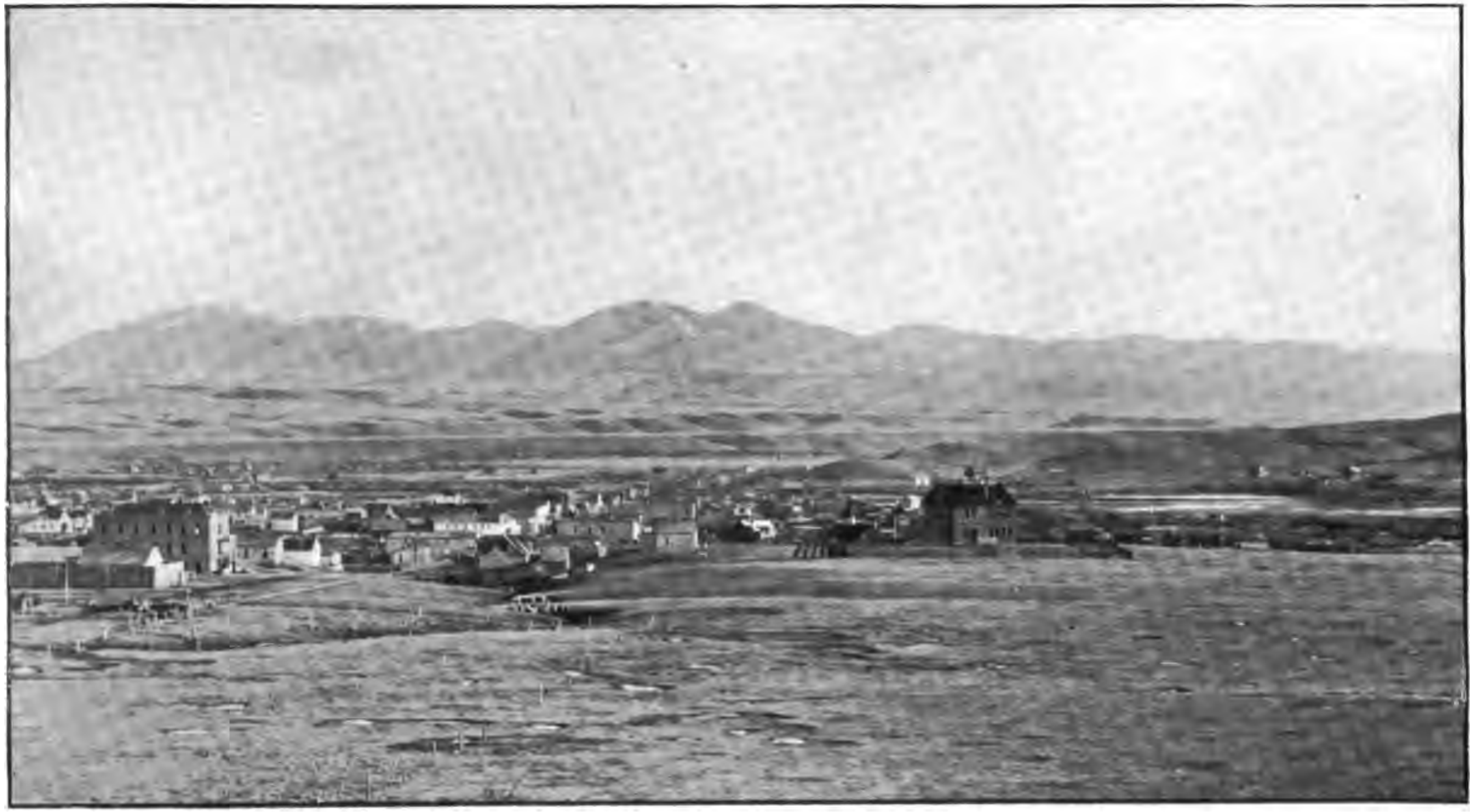
WESTERN FOOTHILLS COUNTRY.

The open country around the western end of the Judith Mountains is of smooth, gently rolling, softly contoured aspect, and rarely does one find any outcrops of the rocks. It is composed entirely of the soft strata of the lower members of the Cretaceous in this region. The hills and benches are determined by the sandstone cappings; the wide, open, shallow, and gently winding drainage channels are cut in soft shales. Long, even planation terraces leading down the stream valleys are characteristic features, and one of them is well illustrated in Pl. LXXVI. The appearance and character of the country show that it is cut in almost horizontal beds of the Cretaceous.

Lewistown, in the valley of Big Spring Creek, is situated on the Dakota-Kootanie rocks, and as one approaches the mountains more red beds are passed over, and Boyd and Burnett creeks pass through many gateways of flaggy sandstones of the Dakota group.

On the north side, in the direction of Warm Spring Creek, the same character holds; there are long inclined planes of erosion coming down with regular slope from the mountains; seen in front they are not conspicuous, but in profile they are very noticeable. The divide between Warm Spring and Burnett creeks is wide and low, cut by open, shallow coulées, winding in and out; rock exposures are rare. It is possible that the tops of some of the higher hills in this part of the region are composed of rocks of the Benton group, but exposures of these soft, black shales are so uncommon, because of their easy weathering and degradation, that none were found in the time which could be devoted to this object.

From any point in this open country to the west of the mountains one sees their bases surrounded by a chain of foothills, beyond which the slopes ascend abruptly, with imbricated outcrops of white limestone gradually rising one above the other to the crest line, the scallops being formed by steep ravines cutting through the sharply upturned beds of heavy Paleozoic rocks. The line of foothills around the outer slope is formed of the heavy, resistant sandstones of the Dakota-Kootanie and Jurassic formations, the shale bands being marked by annular valleys between them. The sandstone outcrops are each marked by fringing growths of yellow pines, and there is a remarkable uniformity



LEWISTOWN AND THE JUDITH MOUNTAINS.

of appearance in this chain of outer flanking foothills, separated from one another by stream courses which have cut narrow ravines through them, with sandstone gateways. The only variation in appearance is their length along the strike of the beds. They may be seen on the topographic map as small outer hills, or may be distinguished by the sudden lengthening of the spur contours.

BURNETT CREEK DOME AND LACCOLITH.

Following up any of the channels of the streams coming from the western end of the mountains, one finds that the dip of the beds, as shown in the sandstones passed, is away from the mountain uplift, and the dip becomes steeper until, when the Paleozoic rocks are reached, it has attained angles of from 30° to 40°. Each of these drainage channels except Burnett Creek, as soon as the heavy limestone of the Carboniferous is reached, ends in a very steeply rising ravine, incised in the limestone, which gradually grows smaller and shallower as it ascends and dies out at the crest of the ridge. The angle of ascent being less than the dip of the beds, the various strata are cut through, giving rise to the imbrication of the outcrops along the mountain side which is so characteristic a feature of this end of the range as seen from below. All of these gulches are dry, and only when the foothills are reached do the seepages begin.

Following up the course of Burnett Creek, however, one finds that when the gateways of Dakota and Kootanie sandstones are passed the channel, which carries a running brook, does not die out upward in one of the steep gulches described above, but continues with a very gradual rise through a canyon cut in the Paleozoic rocks. Leaving the Dakota and Kootanie, one passes the sag which marks the soft beds of the Jurassic and forms a couple of side drainages, and, entering the canyon, passes, while slowly ascending, the whole Paleozoic section from the Upper Carboniferous down through the Siluro-Devonian to the Cambrian. The dip of the beds downstream being very steep, as indicated above, the canyon is very short—about half a mile in length. In spite of bold crags and picturesque scenery, it does not afford good sections for geologic study, as the outcrops are much broken down and covered with talus or vegetation. Passing upward through the canyon, one enters a deep V-shaped valley, which soon forks. The valley is here cut in the greenish conglomeratic Cambrian slates, whose outcrops, considerably indurated, can be occasionally found. As soon as the valley forks both forks are found to be cut in porphyry, whose slide composes the slopes. The valley is heavily wooded with small pines, and a passable wagon trail leads up the main fork toward some mining prospects. At the juncture of the porphyry and Cambrian the stream breaks out in large springs, which form a little swampy area; above this the channels cut in porphyry-wash are dry.

If, instead of ascending the stream bottom, where the outlook is hidden by the pines, one climbs a thousand feet upward over the steep, wooded slopes to the crest of the horseshoe-shaped ridge so well shown on the topographic map, and reaches the point which forms one end of the heel of the shoe, he obtains an excellent view over this inclosed basin. It is seen to be a deeply cut, funnel-shaped basin with a diameter of about 1½ miles across from rim to rim (see fig. 36). Toward the north, at the toe of the shoe, the ridge rises in a peak to its highest point, over 6,000 feet. This represents the calk of the shoe, while on the western side the curving ridge is interrupted by several points before it declines to a last and lower point, from which it sinks abruptly to the canyon. On the east side, to the southeast of the high peak, is another twin peak, from the eastern point of which a high ridge runs eastward, which continues the mountain crest line in that direction; this point is just above the New Years mine. From the western point of the double peak a low, broad divide, heavily clothed with young pines, extends southward to the double peak which ends the ridge.

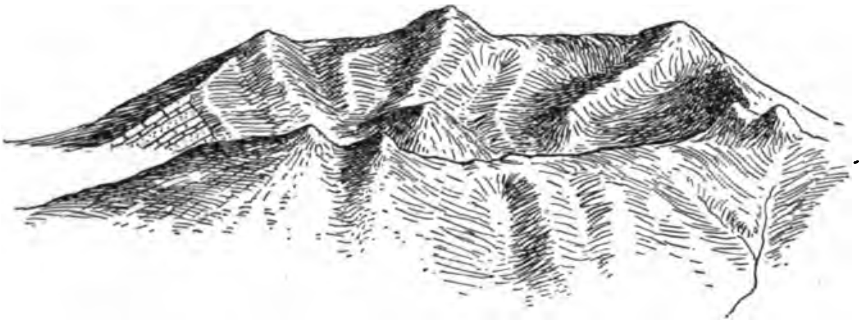


FIG. 36.—Stereographic sketch of Burnett Creek Basin.

The interior of the funnel-shaped basin is cut by ravines running sharply downward and converging toward the center. In the center there rises a hill of porphyry, which divides the drainage into two main branches. The interior of the basin is heavily covered with small pine wherever there are porphyry slopes, as are the north and west sides of the spurs; the east and south slopes, of Cambrian shales, are open. There are enough of these openings, in combination with rugged outcrops or long talus slides of porphyry, to enable the main geologic features to be readily seen. The double peak which forms the eastern heel of the shoe is composed of dark limestones of Silurian and Devonian aspect, the beds dipping sharply south. Descending northward to the broad divide, one finds the Cambrian shales, greatly indurated, standing on end, with strike along the ridge; a short distance beyond they are in contact with a rotted porphyry of a buff color. The band of Cambrian shales in a few rods changes its direction of strike more to the eastward and is cut off by the porphyry which breaks across the horizons.

This mass of porphyry now forms the divide extending some distance down both slopes to a point near which the south slopes of the west New Years Peak begin, where the Cambrian shales are again met, with strike northwest and dip at a small angle southwest. This is abnormal for the general structure, according to which the beds dip outwardly around the circle in a domed anticline, and is probably caused by the intrusion of the porphyry mass of the west New Years Peak. This Cambrian is much covered by porphyry talus, and its exact thickness can not be told. It appears to wedge out along the divide, and to the northwest to run down the hill to meet the heavy mass of Cambrian forming the inside slope of the basin. Rhyolite or quartz-bearing porphyry of the same decayed type just mentioned forms the west point of New Years Peak, the contact between it and the limestones lying in the saddle between the two points; and on either side, north and south, runs a gulch, one side of which is porphyry slide-rock, the other limestone, so that the gulches are thus strike-and-contact ones. The limestone at the contact on the saddle is considerably altered and metamorphosed by the igneous rock. It is of a light-purple to red color, a peculiarity which is assumed by certain horizons of the Devonian, or what is believed by its relation stratigraphically to the Carboniferous to be such, no fossils being present.

On the north side of this porphyry peak the igneous rock is continued across the saddle separating it from the high peak which stands on the most northern part of the ridge at the extreme head of Burnett Creek. The porphyry is continued a short way up the slope of this mountain, and then gives place to Cambrian shales of the usual greenish, conglomeratic aspect, much indurated, with strike northeast and dip sharply northwest into the hill. A short distance below, on the hill slope, other outcrops appear with the dip reversed, and there is at this point some disturbance of the structure due to the intrusion of masses of porphyry, an intruded sheet lying in the Cambrian shales below the high point southwest, on the inside slope of the basin. These shales on the north side of the saddle run down in a strike-and-contact gulch similar to the ones described above.

On the slope of the high point there appears a considerable thickness of Cambrian, about 100 or 150 feet, which is succeeded by blackish limestones supposed to be the Jefferson (Silurian) formation, followed by the chocolate-colored limestones of Devonian aspect. This continues to the top of the peak, which carries a thin, small, intruded sheet of porphyry. To save repetition it may be said that from this point to the end of the ridge, where it sinks to Burnett Creek, the strike is always in the general direction of the ridge, while the dip, which varies from 30° to 40°, is down the spurs toward the open Cretaceous country—that is, normal to the dome structure. Along this crest the dark Siluro-Devonian limestones form the common outcrop; when the crest line sinks a little they are thrown on the outside and the Cambrian slates advance to the divide; as the latter winds, it crosses the strike of the beds obliquely. The Carboniferous beds are just on the outside, and as the spurs run down, the massive bed near the top, a persistent ledge in the measured section (see p. 471), forms a shoulder on each spur.

At the high triangulation point the Carboniferous, here full of crinoid stems and badly preserved corals, advances to the crest line. Below this point and to the southwest the dark, chocolate-colored limestone appears again, forming some very massive outcrops. The rock is here full of curious vermicular markings of a light color.

The whole interior of the basin is filled with a great mass of quartz-porphyry cut into by steep descending ravines. The portion exposed is somewhat oval in shape, about a mile long by one-half mile wide. In the center it rises into the hill which divides the two main forks of the stream. On the basin slopes it is everywhere in contact with the Cambrian shales, which are indurated but not greatly metamorphosed. As the porphyry is more resistant to weathering than are the shales, the point of contact on each descending spur is apt to be marked by a rising shoulder of porphyry, often seen in considerable crags. The porphyry itself is of a brownish color, largely altered, and breaks into small angular fragments which furnish long reddish-brown talus slides.

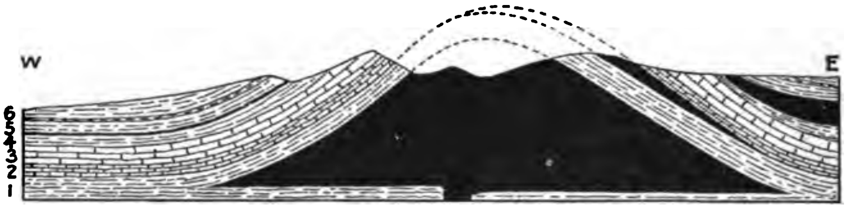


FIG. 37.—East-west section through Burnett Creek dome and laccolith. Black=porphyry; lower broken lines=Cambrian; smaller rectangles=Siluro-Devonian; larger rectangles= Carboniferous, with Jurassic and Cretaceous shale above. Figures indicate height above sea level, in thousands of feet.

The geologic features of this mountain mass at the head of Burnett Creek have been given in some detail because the structure of this portion of the mountains illustrates most clearly, and affords a key to, that of the remainder. From what has been given above it is plain that there is here, as is so clearly shown on the geologic map, a domed anticline, in which the doming up of the strata is due to the laccolithic intrusion of a great mass of porphyry beneath into the easily separated shaly Cambrian beds. The dome has been dissected on the top and the sedimentary cover stripped back from the apex of the laccolith, which is just beginning to emerge. This is most clearly illustrated in fig. 37, which shows an east-west cross section through the middle of the laccolith and its covering load of sediments. It shows also the upper intruded lenses of porphyry, the top portions of which, like the sediments, have been cut away by erosion. The structure is clearly seen on the geologic map, with the central mass of porphyry and the encircling bands of sedimentary strata in proper stratigraphic order, the crest line of the ridge being formed by the resistant limestone horizons.

RUBY GULCH.

The branch valley which leads down from the eastern side of the Burnett dome to the southeast, into Boyd Creek, is known as Ruby Gulch. The name was given it from the small red garnets, coming from the metamorphosed Cambrian at the head of the creek, found in the stream by those washing for gold. In the upper part it is an open, almost treeless basin, with gently descending slopes of light-colored Carboniferous limestone, which meet in a rather flat floor cut in Jurassic and Cretaceous rocks. On the western side of the valley a spur runs out which rises in a low, oblong hill, elongated down the valley; its slopes rise quite abruptly from the stream bottoms which it divides. It consists of a mass of porphyry intruded in Jurassic beds and uncovered by denudation. The rock composing it is of the usual rotten, crumbly, buff-colored type. On the southwest side of this mass the Jurassic shale beds, as usual, are cut out into a drainage channel, but where the strike crosses the spurs they form a line of wooded hillocks on the slopes. Southwest from here the spurs descending steeply from the double peak which forms the eastern heel of the Burnett horseshoe ridge, as they approach the level of the lower country, are prolonged outward, as shown on the map. The dip of the upper Carboniferous beds suddenly flattens out, and within a quarter of a mile or so becomes nearly horizontal. The limestone forms here, in fact, a low, flat dome, cut across by two streams, branches of Boyd Creek. This dome is open and grassy, and standing in the center of it one sees the southern part encircled by the wooded hills of the Kootanie coal sandstone, the Jurassic beds forming a subordinate row of lesser hills in front of them, their crests determined by the Ellis sandstone. It is clear that the structure here is dominated by a lens or flat laccolith of porphyry, which lies under the heavy Carboniferous limestones, arching them up into a low, flat dome, the structure lines of which may be seen on the geologic map (Pl. LXXV). The two drainage channels unite before reaching the encircling Kootanie beds, and pass out through a sandstone gate. On the western edge of this dome the beds have been cut away to a lesser degree, and rise in a long hill covered with tall pines, shown on the map by the southward extension of the 5,000-foot contour. From its position it can be easily seen that it is a strike ridge, the beds dipping east. Ruby Gulch cuts along the eastern limb of this dome in the Jurassic beds, which, on the east side of the stream channel, rise in another long strike ridge following down the valley. Both ridges on either side are cut across by short, dry ravines, or wind gaps, which do not serve for drainage purposes, and the explanation of whose presence must be sought in a certain geologic structure to be presently explained.

It will be noticed, by reference to the geologic map, that on the northeast side of Ruby Gulch there is an elongated patch of Cretaceous strata belonging to the Kootanie and Dakota groups. It is a still uneroded remnant, lying in the end and side of the synclinal half-boat at the head of the gulch. As one passes down the gulch from the head, one sees that the beds feel the influence of the Pyramid Peak intrusion and are thrown back until they stand nearly on end, so that the plane projection of the map gives almost at one point the actual thickness of the sediments from Cambrian to Dakota, provided none of the softer beds are slipped back, as often happens. The strike is northwest; the dip is 75° to 85° southwest. The beds of the Cretaceous are thrown back so strongly that they have yielded and broken, and are now standing faulted against the Jurassic formation of the other side of the valley, which dips gently eastward, away from the low dome described above. The actual line of the fault is covered; at the head of the valley it probably dies out. On the long spur running down from Pyramid Peak into Ruby Gulch, at the point where on the map this spur approaches the 5,000-foot contour line as it crosses Ruby Gulch, the Jurassic has a dip northeast of 20°. The upper bed is the conglomeratic limestone, full of gryphæas near the top of the Jurassic section; it slopes down a little hillock to meet the red beds of the Dakota. A few feet beyond is the sandstone next above the coal sandstone, which strikes northwest and dips 75° southeast. The distance from the last outcrop of Jurassic to this sandstone is about 75 feet, and the fault and amount of its throw are most clearly indicated at this point. Its hade is of course unknown, but is probably southwest. The amount of throw would be indicated at about 350 feet from the measured sections. Down the valley the same general relations are held until the hill of porphyry on the west side of Pyramid Gulch is met. This mass of igneous rock will be mentioned again later; it is sufficient to say here that it lies between the heavy beds of the upper Carboniferous and the lighter Jurassic, the latter stretched out by the bulging mass of porphyry and ending in the west slope in a series of upturned and torn sediments, most of which, so to speak, fray out in the porphyry, as shown in a general way on the map. The Kootanie beds are also thrown back by this intrusion, which carries the fault line along in the same direction as before. The red beds are still seen in some little spurs, and end finally in a grassy meadow on the drainage area of Pyramid Creek.

This area of Cretaceous is marked by an abundance of pines, especially on each band of sandstone as it crosses the spurs, and by a series of springs which break out near its base, the water from which runs but a short distance, when, entering the Jurassic across the fault line, it disappears in the limestone beds. Ruby Gulch itself is not only dry (except for these springs), but throughout the greater part of the valley there is not even a stream channel, a dry, grassy meadow stretching unbroken from slope to slope, the drainage being entirely under ground.

If one stands at the lower (southeast) end of the fault line described and looks upward along it to the northwest, he will see that it marks the

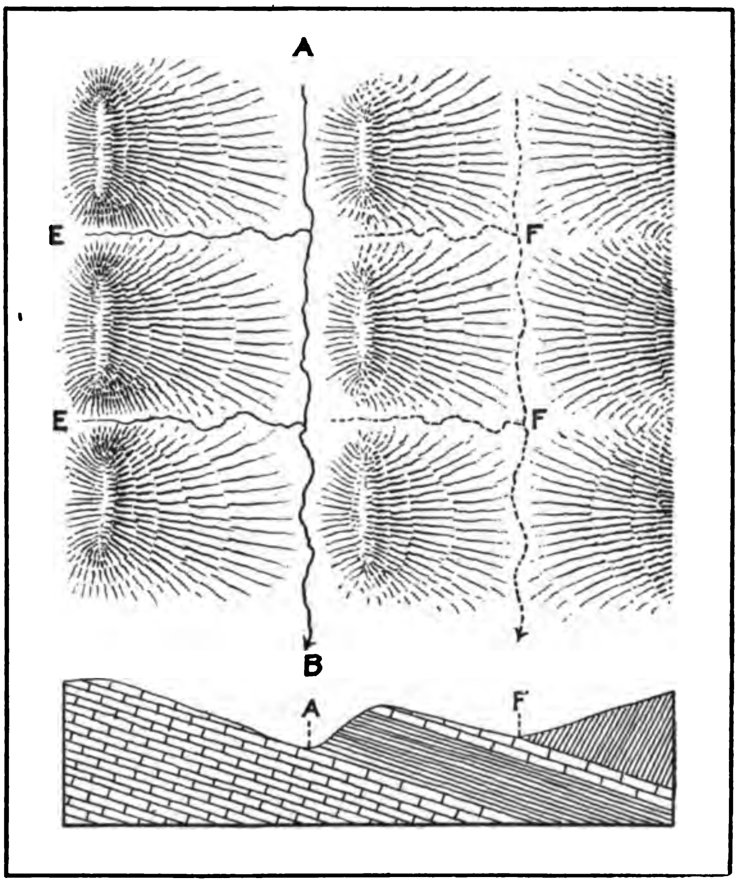


FIG. 38.—Sketch map and section of Ruby Gulch. A B, course of present Ruby Creek; F F, former course along fault line; E F, former drainages. Cross section: A, present channel; F, former channel.

direction of a shallow but distinct valley, which stretches in a general way at its upper end parallel to the present Ruby Gulch. The strike Jurassic hills between these valleys, as mentioned above, are cut across by wind gaps, as are also the Carboniferous hills on the west side of Ruby Creek. The whole relation shows clearly that the former valley drainage ran down in the direction of the fault, and that from the arch of the large dome west the drainage ran into it by several eastward-running drains. Eventually, however, the stripping of the laccolith cover revealed the soft Jurassic beds, which at once determined the new line of drainage, leaving the former valley at a higher level, with the ancient cross drainages into it showing as wind gaps in the ridge intervening.

This is shown in the accompanying figure (fig. 38, p. 493), and in the cross section is shown the former valley line along the fault at F, and that of the newer narrow channel cut out in the soft Jurassic at A.

PYRAMID PEAK.

The ridge which connects the Burnett laccolith with the large one in which Alpine Creek takes its rise, and which will be described later as the Alpine laccolith, contains an area of intruded igneous masses, one of which gives rise to Pyramid Peak. From the line of contact of the intrusive mass of west New Years Peak with the lower Paleozoic limestones, the ridge rises sharply up in a crag of Carboniferous limestone, giving rise to New Years Peak, from which point the divide sinks again. The summit is made of Carboniferous limestone, and the beds are considerably broken; on the spurs they dip down from each side, and the ridge may be considered the apex of an anticlinal fold sharply compressed at the top. On the divide there is a hill made of limestone, and east of it the beds again flatten out, giving rise to a table about half a mile long and a quarter of a mile wide, covered with a thick growth of pines and containing in one spot one of those sinks or old drainage pipes so often found in flat-lying limestone areas.

Farther east the beds begin to tilt sharply up and the ridges rise into the projection known as Pyramid Peak. Climbing upward, one passes over the Paleozoic section, the dark-colored Siluro-Devonian limestones succeeding the lighter-colored Carboniferous ones, and these in turn giving place to the conglomeratic shales of the Cambrian, here greatly indurated. From this point to the top all is composed of rotted, light-brown to whitish porphyry (rhyolite-porphyry), breaking into small, angular bits. The next point eastward is also composed of the same chippy, white porphyry, beginning in the saddle between the two peaks. In this saddle Cambrian slates occur, extending up Pyramid Peak a short distance and dipping back into the slope. There is a thickness of fully 75 feet of them shown, and how much thicker they may be is unknown, as porphyry slide-rock covers the slope. On the east side of the last-mentioned hill the relations of the sediments are precisely the same as on the west side of Pyramid Peak—the Cambrian, then the Siluro-Devonian, succeeded by the Carboniferous, which rises to another peak terminated by a crag where drainage channels of New Years, Alpine, and Pyramid creeks head up against one another. The successive upturned arrangement of the sediments shown in the saddles on either side of this intruded porphyry mass exists also on the spurs leading down from the two points, the crest of the spurs yielding sections and structure similar to the main divide. On the southeast the intrusion of the porphyry has crowded back the beds until they stand very nearly on end, as previously described. This produces, with the heavy beds of limestone of the upper Carboniferous, a tremendous mass of light-colored crags, which dominate the whole of the valley of upper Ruby Gulch, and are indeed its most conspicuous feature.

The relations existing along the ridge from New Years Peak through Pyramid Peak are illustrated in the following figure:

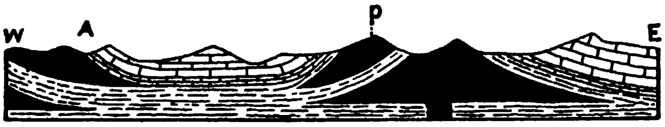


FIG. 39.—East-west section through New Years and Pyramid peaks. Porphyry in black; Cambrian in broken lines; Siluro-Devonian in small blocks; Carboniferous in large blocks. A, New Years Peak; P, Pyramid Peak.

The drainage channels from the porphyry masses have cut out the Cambrian slates on both sides, forming strike gulches, as may be seen by reference to the map. As these gulches descend everything becomes covered with porphyry slide-rock, and the relations of the strata are best seen on the exposed backs of the spurs. The Silurian limestones surrounding these intrusive masses of porphyry have been considerably altered and mineralized by deposition of quartz in places, formation of calcite nodules, etc. This has led to their being prospected, and in one place considerable work has been done, but the mine has not yet advanced beyond the prospect stage. So far as geologic conditions indicate, there is no reason why ore bodies should not be found in connection with these porphyry masses and their contacts.

PYRAMID GULCH.

This is the next tributary to Boyd Creek on the north side above Ruby Gulch. In many respects it resembles the latter. Like it, it has a dry drainage channel, the water passing underground its whole length, and even in flood time appearing on the surface only in its upper course, the lower part showing a dry, grassy meadow without stream channel. In its longest course it extends from Pyramid Peak to Boyd Creek. A number of drainage channels come into it from the east, none from the west. The dry, steep gulches leading down from the mountain converge into a short, rocky canyon with limestone walls as the sharply turned-up beds of the Paleozoic are passed. A deeply cut, narrow valley, with both walls of porphyry, succeeds, and as it then passes out into the Jurassic formation the valley opens into the general one of upper Boyd Creek, the pines of the upper course giving place to the groves of aspen and thickets of the lower country.

The mass of porphyry which is here cut through, as may be seen on the geologic map, lies intruded between the steeply upturned beds of the upper Carboniferous, which have been tilted not only by the Pyramid Peak intrusion but also by the great laccolith of Alpine Creek and the lighter, softer strata of the Jurassic. As will be shown in the course of this paper, and as may be seen by inspection of the geologic map, this horizon plane has been frequently the seat of igneous intrusions.

On the west side of Pyramid Gulch this porphyry rises into a prominent wooded hill which dominates the general lower basin inclosed by the higher Carboniferous ridges and traversed by Ruby, Boyd, and Pyramid creeks. Around the western and southern base of this hill the sharply tilted strata of the Jurassic and Cretaceous are seen pushed back by the intrusion, away from the Carboniferous. At the south base of the hill there is a little saddle, and the spur again rises into another subordinate shoulder of porphyry, which terminates it. In this saddle are found the Jurassic and Cretaceous, with dip toward the south; in the space of a few yards the sandstones of the Jurassic are found, with strike northwest and dip northeast, against the beds just mentioned, and it seems altogether probable that the faulting of the Jurassic against the Cretaceous, which has been mentioned as occurring about a mile up the valley, is continued, passing through this saddle and dying out in the meadows to the east. At least the trace of it is there lost.

Other drainage gulches coming into Pyramid Gulch from the east side have the same character mentioned above where they cut through the porphyry mass. The contacts of the porphyry have been prospected, but no large amount of work has yet been done. There is a considerable quantity of good timber in the gulches and on the spurs, but the entire lack of water in the stream channels is a great drawback to mining. Water is found by digging wells in the porphyry débris bottoms. The nearest surface water in summer is found in springs in the Cretaceous shales to the west. On the east side this mass of porphyry also ends in a gulch, but in its upper portion, where it comes in contact with the Carboniferous formations, it has thrust itself into them in intruded sheets, which are separated by long masses of limestone wedging out into the porphyry and altered by the contact. These relations are best seen on the crest of the spur, where three intrusive sheets are to be found. The porphyry of this mass is of the usual whitish-buff or light-brown, altered, chippy type.

The other little intrusion of porphyry mentioned above, which is south of the high hill, appears to be an eroded remnant of a sheet or thin lens intruded into the Jurassic beds and tilted by the rising of the large, low dome to the west, which has been already described. The porphyry is similar in character to that of the larger mass to the north, but contains occasional large phenocrysts—that is, porphyritic crystals of feldspar. It forms a small wooded knoll, with light-colored slopes of porphyry débris.

In the gulch which limits the large mass of porphyry to the southeast, and where it is intruded among the limestone beds in sheets, is seen the northwest edge of a tilted dome in the heavy Carboniferous beds. The breadth of this low anticlinal dome or blister is not much more than a half mile. It lies tilted up at a low angle on the generally domed-up beds of the Paleozoic which slope down to the west from the high divide ridge running north from the triangulation point shown on the map, a mile north of Flat Mountain. The attitude of the beds forming the blister is precisely like that of an inverted saucer resting on the roof of a house. It is caused by a lens of porphyry intruded among the heavy Carboniferous beds, a horizon which has only in a few cases been the seat of intrusions of igneous rock. At the upper edge, near the ridge, the erosion of the beds has peeled back the cover, allowing the edge of the porphyry lens to appear, and it may be seen curving round on the map. In nature it is beautifully seen from above, the long, bare, light-colored slopes of the Carboniferous limestones contrasting strongly with the protruding edge of the porphyry, whose course may be readily traced by the dense and almost impenetrable thicket of young pole-pines growing on it Several minor gulches which cut across this low dome dissect it excellently for a study of its structure, but they do not penetrate deep enough to reach the porphyry below. At that spot on the dome where the beds are horizontal, eroded and broken-down remnants of a sandstone of a light-gray color are found. The area is well wooded with young pines, and the relations, so far as can be told, would seem to indicate that a small area of Jurassic is still lying uneroded on the Carboniferous. Below this point on the hill the drainage has cut a small, narrow canyon into the back of the anticline, exposing a beautiful descending arch in that horizon of the massive Carboniferous which forms a persistent ledge near the top of the formation. Of course only a very small segment of the circle is shown, but the radius of the curve can not be far from 100 feet.

The spur on the outer edge of this tilted dome and next to the large porphyry mass to the west which has been already described is very nearly a strike spur. In descending it one crosses the formation at an acute angle and passes over the whole section as the crest of the spur curves to the south, passing from bare limestones to the wooded beds of the Jurassic, and finally, in the valley, nearly reaches the top of the latter formation—a little hillock that ends the spur, showing the characteristic bed full of gryphæas, which makes such a valuable reference plane in this formation.

A cross section of this almost concealed lens of porphyry is shown in the geologic cross section A-A of Pl. LXXXII.

In the valley of upper Boyd Creek, between the Ruby and Pyramid drainage areas, there lies a rounded, wooded hill, shown on the map by a single contour. This hill is nearly the central point of a very small domed uplift, quite similar in character to the large one 2 miles or so to the west. It is believed to represent a small concealed lens of porphyry. The structure is shown at a number of points where the outcrops of the Jurassic are found dipping away from the hill at moderate angles. Just north of the hill there is a very low divide, over which a road passes from Ruby Gulch to Pyramid and upper Boyd creeks. North of this divide there are some hills and a ravine or two in which exposures of the rocks give a moderately good section, showing the upper Jurassic, and also a thin sheet of intruded quartz-bearing porphyry, which lies conformably in the strata. Beyond this the Jurassic comes against the Cretaceous, and as the two dips are opposed to each other within a short distance, it is believed that the fault already mentioned must pass through here, to die out in the meadows below.

The top of the central hill, which exposes the lowest beds in the uplift, is wooded and covered with soil and vegetation. Everywhere on it one sees fragments of a dove-colored, thin-bedded, chippy limestone. No fossils were seen, and it is uncertain whether the beds are Jurassic or upper Carboniferous. A little area of Carboniferous has been shown on the geologic map.

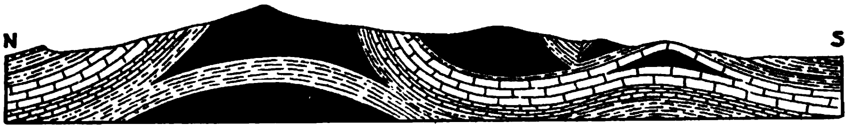


FIG. 40.—North-south section through peak east of Pyramid Peak. Black=porphyry; lower broken lines=Cambrian; smaller rectangles=Siluro-Devonian; larger rectangles=Carboniferous; upper broken lines=Jurassic and Cretaceous.

Some of the relations which have been discussed can be better seen from the accompanying section (fig. 40), which is drawn almost north and south through the porphyry peak next east of Pyramid. The section is swung a few degrees west of south to cut the different porphyry masses.

UPPER BOYD CREEK.

Upper Boyd Creek is closely followed from its mouth to its source by the mail road from Lewistown to Giltedge, which passes over the high divide just north of Flat Mountain. From its source in the springs which rise under the shadow of Kelly Hill to its mouth as it empties into Big Spring Creek it is a running stream throughout the year, small at first, but greatly reenforced by underground waters which burst up as springs in its bed. As one follows up the mail road, he finds the red earths and sandstones of the Dakota group everywhere prominent, the dry drainage channels descending to the creek being little canyons with cornices and buttresses of these sandstones.

The valley bottom, while not wide, is fertile and well ranched. Eventually the last and lowest sandstone is reached, that above the coal, which ascends from the creek in a long, prominent ridge covered with pines, which turns westward and passes over the south limb of the domed anticline already described. Across the stream rise the high, pine-covered slopes of Kelly Hill. The valley bottom is here cultivated, and the color of its soil changes to a deep black, due to the coal and coal shales whose outcrop crosses the stream at this point. The Kelly ranch lies in the meadow just above. The coal which is under this sandstone ridge, if of good quality at this point, should be in a favorable attitude for working.

Kelly Hill.—Following the road, one sees the steep slopes of Kelly Hill rising more and more abruptly until, on its north side, they ascend sharply, with but little talus, from the valley bottom to a quite imposing crest several hundred feet above. They are composed of the light-colored limestones of the Carboniferous. The gulch is cut in the Jurassic beds, and these may be seen as wooded hillocks resting in normal position on the flanks of the bare white limestone spurs coming down from the high triangulation peak. It is therefore clear, to one seeing this imposing wall of limestones of the Paleozoic rising so sharply above the Jurassic, that a fault must exist here. Toward the divide it may be seen that the fault dies out in the massive Carboniferous in the end of a synclinal fold, the massive outcropping ledges showing the turning and gradual change of dip of the strata. The dry limestone gulches at the head of the valley contain a considerable quantity of excellent timber, which, however, is being rapidly cut off.

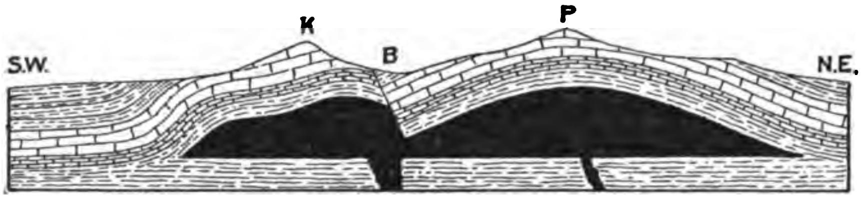


FIG. 41.—Cross section through Kelly Hill (K) and △ point (P) 2 miles northeast. (Explanation as under fig. 40, opposite.) B=Boyd Creek.

If the slope of the hill is followed around to the southwest, crossing some dry gulches full of copsewood, the Jurassic beds finally appear, and beyond them on the hillside the red earths of the Dakota. On the west slope there is a small spring-stream which passes through a gateway in the sandstone, a road from below also ascending at this point. On the slopes of this hill the beds are again found in their normal position and the fault has died out. The dip of the beds here is about 30° a little south of west, and the succession of the outcrops shows the coal sandstone with the red beds beyond it in very close proximity to the upper Carboniferous. It seems clear that the rise of the anticlinal dome, with the bulging and compression of the sedimentary beds, has slipped back the soft shale layers of the Jurassic and Kootanie, bringing the Carboniferous and coal sandstone very near together, with but little intervening Jurassic. From here southward the beds resume their normal relations, dipping away regularly from the south arm of Flat Mountain. They are cut through by several wooded gulches, while the coal sandstone, which forms its usual wooded ridge in facing toward the mountain, gradually rises to the divide running southward beyond the limit of the district shown on the map and separating Boyd Creek from McDonald Creek drainage areas.

From phenomena studied elsewhere in the Judith Mountains, it appears most probable that Kelly Hill is due to an intrusion of porphyry in the Cambrian shales, which, along the north limb of the dome, has lifted the beds with so much force as to rupture them and to raise them until the Carboniferous is brought against the Jurassic. It seems probable, also, that the intrusion is connected with that of the triangulation-point dome, as shown in fig. 41 (p. 499).

FLAT MOUNTAIN.

This is the large flat-topped elevation which is the most southern one shown on the map. From it there runs southward a divide which is much lower and which passes into a group of hills most inappropriately known as the Little Snowies, foothills of Big Snowy Mountain. Flat Mountain is, both topographically and geologically, the southern terminus of the Judith Mountains. On top it is somewhat gently undulating, with open, park-like spaces alternating with groves of small pines and stretches of white, level-lying limestones. On the outer slopes of the mountain these limestones are very apt to break down into a low cliff, and from the open country to the east, to the south, or to the southwest, these long lines of white ledges of the upper Carboniferous are very conspicuous, and sharply define the mountain as they rise above the dark pine-covered talus below. These ledges are in the main defined by the 5,000-foot contour line, which passes around the mountain. The streams, and notably McDonald Creek, have cut back into these limestones, forming large amphitheaters, with walls of the light-colored rock. Below the outer débris slopes are those of the Jurassic, which form the upper part of the foothill country. Beyond this is the Kootanie, with the prominent wooded ridge of the coal sandstone. On the various branches of the heads of McDonald Creek these formations are deeply trenched into a series of wooded ravines, presenting a country highly accidented on a small scale. The numerous sandstone outcrops dip down the streams and often form descending ledges. Below the coal sandstone, along the streams, the red beds and sandstones, which are stratigraphically above it, are everywhere prominent and conspicuous.

All of the main channels on the southeast side of the mountain contain running water, and the country is well ranched. An excellent road, coming from Lewistown, passes over the divide and down McDonald Creek. No porphyry of any kind is found in this portion of the mountains, and it is not seen in the stream gravels. The Kootanie beds, as shown on the map, cross the divide, extending to the edge of the mapped area. South from here the limestones of the Paleozoic are again seen in a prominent hill, and on the main road along a fork of McDonald Creek, not seen on the map, the Cretaceous is faulted against the Carboniferous, the stream at one point cutting the fault line. At several points here the coal has been prospected and mined to some extent, the gentle outward dip of the bed, with its usual elevation on a ridge, placing the seam in a favorable attitude for working. Further details are given in the economic chapter, p. 614.

On the east side of Flat Mountain there is a small subsidiary anticlinal dome in the Jurassic, partly denuded of the Cretaceous. It is dissected by one of the branches of Chippewa Creek, the south fork cutting across it. It is not over a half mile in diameter, and the swinging round and the changing of dip of the heavy sandstone beds enable one to perceive it almost in one view. It is doubtless caused by a small concealed lens of porphyry, very probably at the base of the Jurassic beds, a favored horizon for intrusions.

Flat Mountain itself is evidently a large single laccolith, or a series of laccoliths forming one of the compound type, whose Paleozoic cover has not yet been broken through. Very probably, like the Burnett laccolith, it lies in the Cambrian shales, but it appears to be of a broader and less thick lenticular type. It appears probable that the Kelly Hill uplift is part of the same set of intrusions.

This portion of the mountains, though it has been prospected, does not appear so far to have yielded anything to encourage further work, a fact not surprising when one considers the close connection in this region of the ore bodies with intrusive masses of porphyry or their contacts. Flat Mountain must probably yet undergo a geologic period of erosion before its riches, if it contains any, shall be revealed.

RIDGE BETWEEN FLAT MOUNTAIN AND ALPINE CREEK.

North of Flat Mountain is the divide crossed by the Lewistown-Giltedge mail road. It climbs up through the wooded, dry, limestone ravine at the head of Boyd Creek and, crossing an open flat on the top, winds down through similar steep ravines toward the open country below. North from this divide rise the bare, treeless, white slopes of the triangulation-point peak, covered in places with a scanty growth of grass, but in other spots bare, and exhibiting in its outcropping ledges the geologic structure. On the peak the strata are horizontal, or nearly so, but from this point they dip away in all directions, and the peak represents the center and highest point of a domed anticlinal uplift. Dry, narrow gulches in the limestones dissect it on either side to the east and west. It appears to be caused by an intruded mass of porphyry not yet revealed, and is so shown in the section A–A of Pl. LXXXII.

North of this the upper edge of the tilted lens of porphyry, heretofore described, appears upon the ridge covered with a thick growth of pine; beyond it the Carboniferous is again found. From here various gulches lead down into Whisky Creek. They are all dry, however, and in reality there is no stream, the drainage course, with its various heads, and especially that one which leads up to the edge of the great Alpine laccolith, being familiarly known as "Whisky Gulch." After the uniting of the various channels there is a short canyon leading out through a limestone gate into the open basin of Jurassic and Cretaceous beds. The main ridge passes on northward, with occasional craggy outcrops and slopes of upper Carboniferous limestones showing through the pine trees, until the intruded masses of porphyry and upturned Cambrian shales of the Alpine laccolith are reached.

The ridge has been prospected at a number of places, but none of these prospects have been carried to a point which would indicate that anything valuable had been found.

THE ALPINE LACCOLITH.

By reference to the topographic map it will be seen that Alpine Creek, one of the head branches of Warm Spring Creek, drains an interior basin surrounded by a horseshoe-shaped ridge or divide. It is true that this divide varies in elevation, and that it is broad in some places and very narrow in others, but in the main it follows the horseshoe outline quite closely. It is thus precisely like the basin at the head of Burnett Creek, which has been already described, but is somewhat larger, being about 2 miles across from crest to crest at the greatest width of the oval and nearly 3 miles long.

Viewed from any of the high points which command the outer rim, this basin presents the appearance of a very wide and shallow funnel, cut on every side by descending and converging ravines separated by long spurs with generally narrow and sharp crests, and which in a number of cases, as they descend into the bottom of the basin, form small hills which stand as points on the spur ends. This huge, shallow, ridged bowl presents a very dark and somber appearance, due to the thick growth of small pines which covers nearly every part of it. Occasionally a small patch of gray slope is covered with shale débris or a red-brown streak of porphyry talus, but in general a hue of somber green is everywhere to be seen. The trees which produce it are of varying age; sometimes in the bottoms of the ravines they are of good size, but generally they are small, closely set, and difficult to penetrate, while considerable areas of the porphyry are covered with young trees about an inch or two in diameter, which are packed together with a closeness almost beyond belief, and a description of which would seem incredible to one who had not actually seen them. Such areas are absolutely impenetrable without the use of the ax. Fortunately for geologic purposes, the prospectors have cleared paths through them in various directions.

From what has been said, it will be seen that the Burnett Basin is quite similar to the Alpine. It is, indeed, so to speak, an epitome of it, both topographically, as already shown, and geologically, as will be described. The Alpine Basin is, however, much larger, more complicated in its geologic structure, and less easy to study on account of the denser vegetation.

From the wagon trail from the main highway which passes down Warm Spring Creek up the Alpine Creek Valley, the slopes of the high prominent hills are seen to be composed of Carboniferous limestone with white ledges and outcrops, which at the entrance to the basin narrow down to the stream. They hardly produce a canyon, but rather a deep, V-shaped valley with occasional heavy outcrops of rock along the sides, talus slides, or pine-covered slopes. Through this the stream runs—a noisy brook with a moderate volume of water even in the driest part of summer, the narrow valley bottom through which it passes everywhere cut up by placer works and diggings. The occasional rock outcrops are seen to be, first, the upper part of the massive Carboniferous, which, as usual, forms a projecting ledge with strata dipping downstream—i. e., north, at an angle of about 30° to 35°; along the stream occur outcrops of the Paleozoic series, then an intruded mass of porphyry dipping with the strata and tunneled by prospectors, and lastly the dark-greenish conglomeratic slates of the Cambrian, intruded with a sheet of porphyry, which, rising along the slope, covers the latter with its talus.

The main valley continues deep, narrow, and wooded, with an occasional prospector's cabin, and wherever rock exposures occur they are of porphyry—a rotted, or at least always greatly altered, rather dense, quartz-bearing porphyry, of a rusty, reddish-brown color, much crackled and breaking into small angular débris, the usual type of the mountains. On either side narrow gulches of the same wooded character come in, with occasional porphyry outcrops and a small thread of a stream running in the bottom. This continues to the foot of a rather prominent porphyry hill which stands in the bottom of the valley and is shown on the map. The main stream divides at this point into two forks, into each of which the usual small gulches come down. Both are of the same narrow type, with porphyry débris, and are thickly set with small timber and often encumbered with fallen logs. As these gulches ascend there are open areas on the slopes facing south, the soil made up of fine gravelly débris of porphyry or fragments of the greenish-gray Cambrian shale.

No productive mines have as yet been developed in Alpine Creek, but considerable placer mining has been done, and in several places prospecting of the contacts has been carried on, described more fully later (p. 606).

If one follows the divide, which heads all of the converging gulches around in its horseshoe curve, taking the road which leads upward through the dry limestone ravines from Maiden to the P. K. mine as a starting point, one finds that the sedimentary beds, wherever they occur, dip away from the center of the interior basin at angles of from 30° to 40°, and the strike thus in general follows the outline of the divide. There are some exceptions to this rule, where intrusions of sheets or lenticular masses of porphyry have locally disturbed the general structure of the beds, but in general it becomes evident that the ridge is geologically similar to that of Burnett Creek, and that the whole structure is that of a domed anticline whose top has been cut off and then hollowed out, crater like, by erosion. Continuing up the road mentioned, one passes various intrusive sheets of the rotted quartz-bearing porphyry. Pekay Peak is topped by a crag which gives a magnificent view over the mountains to the east. It is composed of Carboniferous beds, shown by the character of the large corals the rock contains. On the south side of the porphyry hill is the Globe or P. K. mine, to which also an excellent road runs around on the inside slope, past the War Eagle mine, to join the main one coming up the gulch, and affording, where cut back into the hillside, sections of the Paleozoic rocks and intruded sheets of porphyry. In this portion of the uplift the Siluro-Devonian beds are either greatly thinned down by slipping in the uprise or are wanting; they are certainly not clearly to be found and recognized, as on the opposite crest across Alpine Creek. Beyond the P. K. mine—that is, south of it—greatly altered limestone occurs on the divide, and then beyond this the divide is rather broad and variable in height and is composed of masses of porphyry which are the tops of intruded sheets coming up diagonally over the spurs and gulches from Alpine Creek below.

On the outer side, to the southeast below, the massive Carboniferous has retreated down the slopes, and south of Pekay Peak amphitheaters and dry gulches have been cut in the heavy limestones leading down into what is locally called Virgin Gulch; and at the point on the divide above mentioned these gulches are cut at their heads in porphyry, a broad mass of which crosses the spurs, and in Cambrian, whose rough, craggy outcrops of indurated conglomeratic slates and thinly bedded limestones form infrequent but characteristic exposures. As is usual with such gorges, the final gorge of Virgin Creek passes out into the open country through gates of upturned upper Carboniferous limestone. Where the Cambrian occurs on the divide it is open or sparsely clothed with trees, the slope being covered with the broken, chippy débris of the greenish or purplish gray shales. The porphyry, as previously mentioned, is densely clothed with young pine·

Careful search for Cambrian fossils in these beds resulted only in the finding of a minute shell, strongly resembling an Obolella, and in one of the limestone layers fragments of a trilobite. Beyond here to the south another intruded sheet of porphyry advances to the divide and occupies its crest for a long distance.

A wagon trail has been cut through the dense pine, that leads eventually to an open hill on the divide composed of the Cambrian slates, which here show a local disturbance from the general structure, for they strike nearly south and dip 20° W. A spur puts out from the divide, which rises into a peak, called Giltedge Peak, the spur forming a divide which separates the head drainage of Giltedge Creek from the most southerly ravine draining into Virgin Creek. Outward on this spur the grass-covered Cambrian gives place to the dark limestones of the Siluro-Devonian, with a very thin intruded sheet of porphyry, which in turn gives place to the Carboniferous, the latter forming the crag that marks the top of the peak. This, like Pekay Peak, contains numerous fossils, corals, crinoids, etc., but seldom well preserved.

From the open hill of Cambrian slates, which here forms the highest and most conspicuous point on the divide, a long spur runs southeast, dividing Giltedge Creek and Whisky Creek drainages. On this spur crest the Cambrian gives place to porphyry, which is succeeded by Cambrian, and then by the remaining Paleozoic beds, with sharp dip to the southeast. The main divide from this hill sinks rapidly about 200 feet to that portion of the divide which separates the heads of Whisky and Alpine creeks. This is all of porphyry, extending a long distance into Whisky Creek, all the upper gulches at this point being cut in it. On the north side all the head gulches of Alpine Creek are cut in it, and in Alpine Basin all is porphyry, either down the spurs or the drainages. No sedimentary beds are to be found until the upper western slopes of the basin are reached.

As shown on the geologic map, here is found the boundary of an immense mass of porphyry, whose uncovered or exposed portion is of a rudely elliptic outline, which is, roughly estimated, about 2 miles long by 1 mile broad. This represents the upper portion of the main Alpine laccolith, which underlies the intruded sheets and smaller lenses. On both sides of this divide the surface of the porphyry is very irregular and cut into by sharp V-shaped gulches; the slopes are apt to be covered with gravelly débris of rotted porphyry. No prominent outcrops of porphyry are seen; it is broken down into masses of rather small, platy blocks. The rock itself is of a rusty-brown to pale-pinkish color, and is somewhat variable in different parts of the mass, passing from a rather dense porphyry to a form more granular, filled with small feldspar crystals with much less or no quartz and some black spots of a hornblende or pyroxene, and resembling closely in all essentials the porphyries or porphyrites which compose so large a number of our western laccoliths.

The contact of this porphyry mass in the head of Whisky Gulch has been explored, and there are several prospects located upon it, but they have not been sufficiently developed as yet to rank as mines.

From this portion of the divide there are steep slopes to the high points where the divide runs southward to Flat Mountain, heretofore described. Cambrian shales, with intruded masses or lenticular sheets of porphyry, are again met with, similar to those south of the Pekay mine. The spurs that lead down into Pyramid Gulch show the normal succession of the bedded rocks, dipping at sharp angles down the spurs; occasionally thin sheets of porphyry are intruded in them. A number of prospects are located at the contacts on these spurs, but no active development work is being carried on. This character of the divide, or mountain crest-line, continues to the point where Pyramid, New Years, and Alpine creeks head against one another. The spot is marked by a heavy crag of Carboniferous limestone on the divide, the rock there being filled with ill-preserved corals. Just below here, on the slope toward Pyramid Peak, there are deposits of a soft, earthy, red hematite or red oxide of iron, mixed with hard nodules, in the limestone. The material has the brilliant-red color of the brightest red ochers, and has been prospected. A little of this red ocher will color a considerable area of limestone. There is not sufficient of it to make it of any technical value.

The geology west of this locality, toward Pyramid Peak, has been already described. Northward, on the Alpine Creek divide, there is a sharp descent, over porphyry and then Cambrian, to a low saddle cut in porphyry. The heavy limestones of the Carboniferous are seen turning here on several spurs in the direction of their strike. They form the prow of a synclinal boat between the anticlinal dome of Pyramid Peak and the western side of the Alpine uplift, as shown on the map. The porphyry which forms the low saddle is part of an intruded sheet; it is of the usual brownish, rotted type. The divide from here northward rises gradually and is so exactly a repetition of the western side or crest of the Burnett horseshoe ridge that it is unnecessary to repeat the details. A high, prominent hill on it is composed of an intruded mass of porphyry. The rest of the divide is mostly over the Siluro-Devonian rocks, the section of which given in Chapter II was made here. Toward the north the ridge passes over into the Carboniferous, and from here to the point where it slopes down into Warm Spring Creek Valley it is entirely in that formation. On the western side of the basin the inside slopes are mostly of Cambrian, with intruded sheets of porphyry, as shown on the map. These upper slopes are generally open, covered with débris of porphyry, shale, or limestone from the various rocks above; as they descend they begin to be scored by the heads of the inside ravines. Throughout all this part of the region large outcrops of rocks are wanting except when the main porphyry approaches the creek, when it is exposed in some heavy crags. In several places there are heavy slides of porphyry from ascending sheets. Very little prospecting work appears to have been done on these western slopes of the basin, and it is locally considered an unpromising area.

From what has already been said it is now clear that the Alpine Creek dome is due to the intrusion of a great laccolith of porphyry, and that it is precisely similar to the Burnett laccolith. Its history seems to have begun with the intrusion of sheets and lenticular masses or laccoliths of small size in the Cambrian; eventually one of the lower of these became larger and larger, lifting the sediments and their contained sheets and lenses. The intrusion of these latter had already lifted the strata somewhat; the intrusion of the great mass below completed the domed uplift as we now find it. As at the Burnett dome, erosion has cut away the upper portion of the cover and dissected out the crater-like bowl, but the dissection of the crest line in relation to the heavy limestones has been more irregular than at the Burnett dome. The geologic structure is shown in the section, fig. 42 (p. 509), which is taken northwest and southeast directly across the middle of the dome, and it will be seen that it is precisely similar in principle to the Burnett dome and laccolith (fig. 37, p. 490).

NEW YEARS CREEK AND VALLEY.

This valley, called locally New Years Gulch, after the New Years mine, which is located on the crest of one of the spurs leading into it on the west, lies between the mountain upraise of the Burnett anticline and that of Alpine, which has just been described. Essentially it is in geologic structure a synclinal half-boat or prow, and this structure is modified only in its upper part by the intrusive masses of Pyramid Peak, which have disturbed this symmetric arrangement in the lower series of strata. As can be seen on the map, the coal sandstone, which circles around the northwest foot of the Alpine dome, takes here an incurve, and then passes to the west around the Burnett dome. It forms here, as usual, a high, conspicuous, wooded ridge. Inside of this is the Jurassic series, which is either cut down into meadows or, where it crosses the spurs, forms a conspicuous sag or small saddle. When not in the valley bottom it is generally covered with open groves of heavy timber. Above are steep slopes of Carboniferous limestone, which rise rapidly to the crest line. The main valley inside of the coal sandstone forms a rather flat-floored open basin, from which several valleys branch out, which are dry and do not even show in places any stream channel.

On the western side another drainage channel passes through a wooded and copse-covered bottom, into which several gulches from the Carboniferous slopes empty. This is separated from the open basin mentioned by a spur which, ending in the Kootanie beds with the coal sandstone, forms a dark, wooded hill in the valley mouth. Above it the Jurassic saddle forms a very low divide, over which a wagon trail passes. A road leads up the west branch and, ascending steeply by one of the spurs, a short distance below the top of the divide it attains the New Years mine. At this point a sheet of quartz-bearing porphyry of the usual altered type is intruded in the Carboniferous limestones. The beds dip steeply down the spurs away from the Burnett dome, and the porphyry appears to be intruded conformably in them. The sheet consists of soft, disintegrated material without outcrops, and is so covered in places by limestone débris that its thickness can not be given, but it must be considerable. The same remark might be applied to nearly all the intruded sheets of porphyry in this region. The sheet mentioned appears in the next spur west, and forms long talus slides in the intervening gulch. Below this there are at least two and probably three other sheets intruded in the limestones. The New Years mine is mentioned in the economic part of this paper (p. 607). The spurs east of this locality are of quite similar character, and also contain a sheet of intruded porphyry. The gulches between these spurs are dry, and it is not until the Cretaceous beds near the mouth of the gulch are reached that the water attains the surface, in springs, whose branches uniting form a small brook, which is New Years Creek proper. This runs down through an open country composed of the Dakota beds, and, cutting through the anticlinal upraise on Warm Spring Creek, joins that stream.

The country between Warm Spring Creek and the mountain is well adapted to ranching and stock raising, and has the usual character of the rolling, open foothills of the Cretaceous formation.

GILTEDGE CREEK.

By reference to the geologic map it will be seen that the sedimentary beds between the debouchment of Maiden Creek on its open alluvial plain (or, in other words, the mouth of its canyon) and the eastern slopes of Flat Mountain make a great infold, similar in character, in some respects, to that in New Years Gulch, which has been described above. On the map this structure is best seen in the Jurassic and Kootanie, which curve in a great arc. About the middle of the chord of this arc lies the town of Giltedge. The beds are upturned in the central part of this curve by the Alpine laccolith, and the structure is seen in the cross section shown in fig. 42. This half-bowl has three drainage systems—Virgin, Giltedge, and Whisky creeks. The former and latter have been already described.

The main drainage of Giltedge Creek comes down through a very deep, steeply cut V-shaped ravine, which extends back to the main Alpine divide. It is full of timber, and its sides and bottom are full of the débris of the Carboniferous limestones in which it is cut. The spurs on either side are also covered with clumps of pines or show white limestone ledges. Several sheets of porphyry are intruded into these limestone beds, and their outcrops are found on the crests of each spur. This character continues till the top of the Carboniferous is reached. The massive beds then form heavy outcrops, and are seen as ledges descending transversely across the slopes of the ravine. At this point a heavy sheet of porphyry has been intruded in the lighter, thinner beds above the massive Carboniferous. It appears to be conformably interbedded, and its strike is northeast, its dip southeast, like that of the limestones. The porphyry sheet appears on the crests of both spurs; its outcrop ascends diagonally, and, as usual, is apt to be covered by a heavy growth of pines. Situated on this porphyry and at its contact with the limestone are the Giltedge, Chickadee, and other mining properties, which are described in the economic portion of this paper (p. 607). The porphyry itself is, as near as can be told, of the usual quartz-bearing type. It is very greatly altered; so much so in places that it is changed almost to a clay nearly capable of being worked with a shovel alone.

The outer ends of the Carboniferous limestone spurs descend in a sharp slope, generally wooded, to the foothills of Jurassic beds. The stream channel coming down does not cross these beds directly, but, deflected by the sandstone at the top of the Jurassic, and more especially the heavy coal sandstone above it, it follows the course of this interior moat-like valley for nearly a mile or so southward, when, eventually cutting through the coal sandstone ridge, it debouches on the open plain. This valley is of a narrow, shallow character, with an alluvial bottom, composed mainly of débris of Jurassic and Kootanie shale, with thickets of bushes. Up it the ore road from the Giltedge mill to the mine passes. The coal sandstone forms its prominent wooded ridge. On the north end of it the Giltedge mill is situated, as shown in Pl. LXXXVI. It strikes to the south here and dips perhaps 20° E. The coal for running the engine at the mill is mined here, and the seam has been opened in several places.

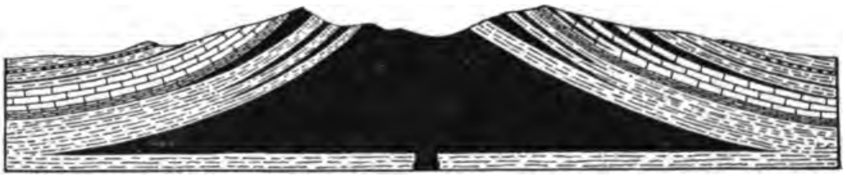


FIG. 42.—Northwest-southeast section through Giltedge Peak and Alpine laccolith. Black=intrusive porphyry; broken lines=shale; rectangles=limestone.

The mail road from Lewistown to Giltedge, descending the limestone ravines of the south fork of Whisky Creek, on reaching the open country at the Cretaceous area, turns northward along the shallow valley inside of the coal sandstone until it reaches the main Whisky Creek, when it follows the stream out through the sandstone gate and turns northward over the red soils of the Dakota beds to Giltedge. This town, which is an active little mining camp, is situated on the creek that bears its name. It is on the Dakota beds, whose red soils are everywhere prominent in the roads and cuttings about the town.

In the open Cretaceous plains country, east of this portion of the mountains, the various drainages are of the seeping character described in the previous chapter, and along their course numbers of ranches are situated. The volume of water is not sufficient for extensive irrigation, but the moist bottoms along the drainage channels yield excellent crops of vegetables or cereals adapted to the climate.

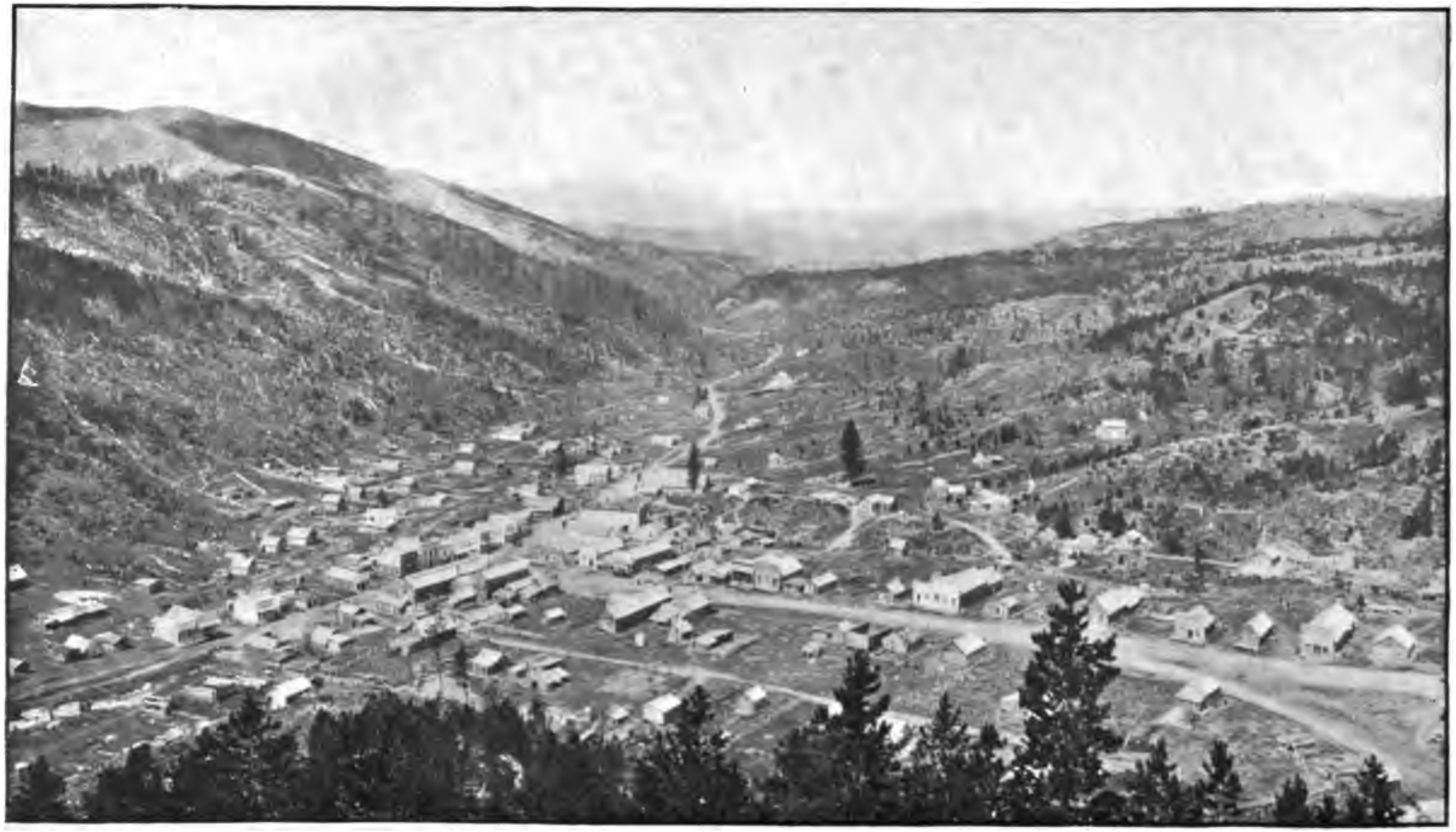
THE MIDDLE PART OF THE MOUNTAINS.

UPPER WARM SPRING CREEK AND VALLEY.

The valley of upper Warm Spring Creek is, near its head, narrow and deeply cut, and between it and Maiden Creek Canyon there is a low divide, crossed by the mail road from the town of Maiden to Giltedge. These two deeply cut valleys and the low divide separate the Judith Mountains into two districts, a southwestern, whose descriptive geology has been given in the preceding portion of this chapter, and a northeastern, the subject of the following one. The division is not only topographic but also geologic, since the area to the southwest is characterized by a certain simplicity of structure, its main features being determined by the three great intrusions of the Flat Mountain, Burnett, and Alpine laccoliths, while the district on the northeast is of a much more complicated character, both in its topography and in its geology, for although its structural features are due to intrusion of igneous rocks there is considerable variety both in the character of the intrusions themselves and in the nature of the igneous rocks composing them.

Briefly stated, the valley of upper Warm Spring Creek is due to the cutting out and erosion of soft shales lying between upturned strata of resistant limestones on one side and intruded masses of porphyry on the other.

The limestones, which compose the southern side of the valley, are of upper Carboniferous age. They form the northern slope of the Alpine anticlinal dome, caused by the intrusion of the large Alpine laccolith. To the east of the Alpine uplift there is another intrusion of porphyry, which has domed up the strata. This will be described later. It is here sufficient to say that between these two uplifts there has been an infold of the strata, in character similar to that of New Years Gulch, but forming the synclinal prow of a longer, shallower, and narrower boat. The symmetry of this has been greatly disturbed, however, by intrusions of porphyry, which have destroyed part of it entirely and so thickened other parts by sheets that the structure is



MAIDEN, FROM THE EAST.

not at first evident. The infold, however, has brought the Cretaceous far up the valley to the very divide at its head. On the south side of the valley erosion has cut away the less resistant strata until the massive Carboniferous has been reached, and its outcrops form ledges whose white imbricating outlines are a conspicuous feature. They are fairly well shown in Pl. LXXVII, on the left. Alpine Creek has cut through them at one point, and toward the head of the valley they are scored by a number of dry ravines leading down from Pekay Peak, and which are indicated in a general way on the map (Pl. LXIX).

At the head of the valley the dip of the limestone begins to flatten out, and the strike swings round from southeast to east and then to the northeast. At this point, which is on the divide between Warm Spring and Maiden creeks, the limestone reaches the prow of the synclinal boat, and it is at a very low point on the divide. It is here cut off abruptly by the intrusive mass of Gold Hill porphyry, the Maginnis mine being on the contact. The last outcrop of the limestone is seen resting as a large tilted block on the divide above the Maginnis mine; it is well shown on Pl. LXXXIV, all to the left of it being of porphyry. The wooded character of these steep limestone slopes is well shown on the left of Pl. LXXVII. Generally speaking, this portion of the Alpine dome—its outer Carboniferous slopes forming the south wall of Warm Spring Valley—is nearly free from intrusive sheets of porphyry, and in consequence, although considerable prospecting has been done in the limestone, no important ore deposits have been developed.

The Jurassic beds, above the Carboniferous, as is so generally the case in these mountains, have been stripped back from the uplift, on account of the soft, erodible nature of the shale horizons, and now form the valley bottom, the limestones, affording small ostreas, and of typical Montana Jurassic aspect, being found in and above the road leading down to Warm Spring from Maiden, where they form small craggy outcrops on the ends of the little spurs coming down from the north. This road and the extreme ends of the little spurs a few feet above it are shown in Pl. LXXVII, and the central portion of the town is on the Jurassic. Above this are the Kootanie and other Cretaceous formations, which also follow the Jurassic up the valley. The intrusions of porphyry they contain will be mentioned later. Both the Jurassic and the Dakota-Kootanie are carried up to the divide in a tilted and somewhat warped condition. On either side the Jurassic has been cut down, as usual, into a gulch, so that these beds, as seen on the geologic map, are left resting in the curved prow of the Carboniferous limestone boat as a tongue-shaped mass, the extreme end of which appears as a tilted pine-covered table of the heavy sandstone over the coal. The road from Maiden to Giltedge, in ascending the divide, passes up a gulch cut in these Cretaceous beds, and the road-cutting affords a section of them. Thus, in ascending, one passes over the red earths and sandstones of the Dakota, and then the black shales, coal, and sandstone of the Kootanie, in regular sequence. The coal has been prospected here, and also in the head of the valley below; but it appears in an unfavorable condition for profitable working. The outcrops of the Jurassic beds, being exposed on both sides of the tongue, cross the divide twice, and in both places cause a low saddle in it. As usual, a sheet of porphyry has been intruded into these beds, and its outcrop follows around through the most southerly of the two depressions. The Jurassic of the extreme end of the tongue forms the usual gulch between the Carboniferous of the west slopes of Sheep Mountain and the coal-sandstone table mentioned above. This gulch forms the extreme head of Maiden Creek. The divide is seen in fig. 43.

To the north this divide rises into the rounded eminence of Gold Hill, composed entirely of porphyry. This portion of the intrusive mass does not have the character of a sheet or laccolith, but is shown by its contacts, by the variety of formations it breaks through, and by its relation to the geologic structure, to be of the nature of an intrusive stock. Its contact with the limestones at the Maginnis mine is irregular, the plane of contact shading in toward the porphyry, as shown in fig. 54 (p. 600). Above the town of Maiden, to the northeast, a couple of gulches are cut back into this porphyry, and one of them leads by a low divide over into the beautiful park at the head of the Spotted Horse branch of Maiden Creek. Beyond this divide the porphyry continues into the high point of Maiden Peak. This porphyry is greatly altered; it weathers down into a gravelly débris in which rock outcrops are rarely seen; a few occur on the sides and at the top of Maiden Peak. The character of its smoothly modeled, pine-dotted slopes is well shown in Pl. LXXVIII.

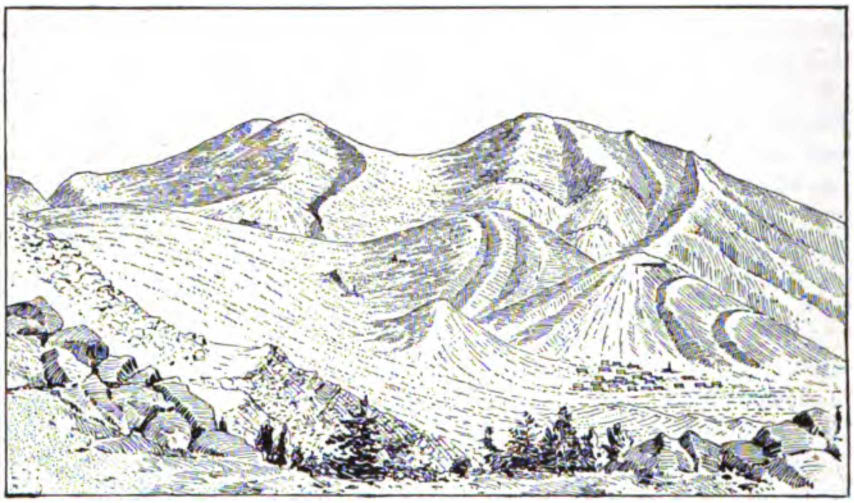
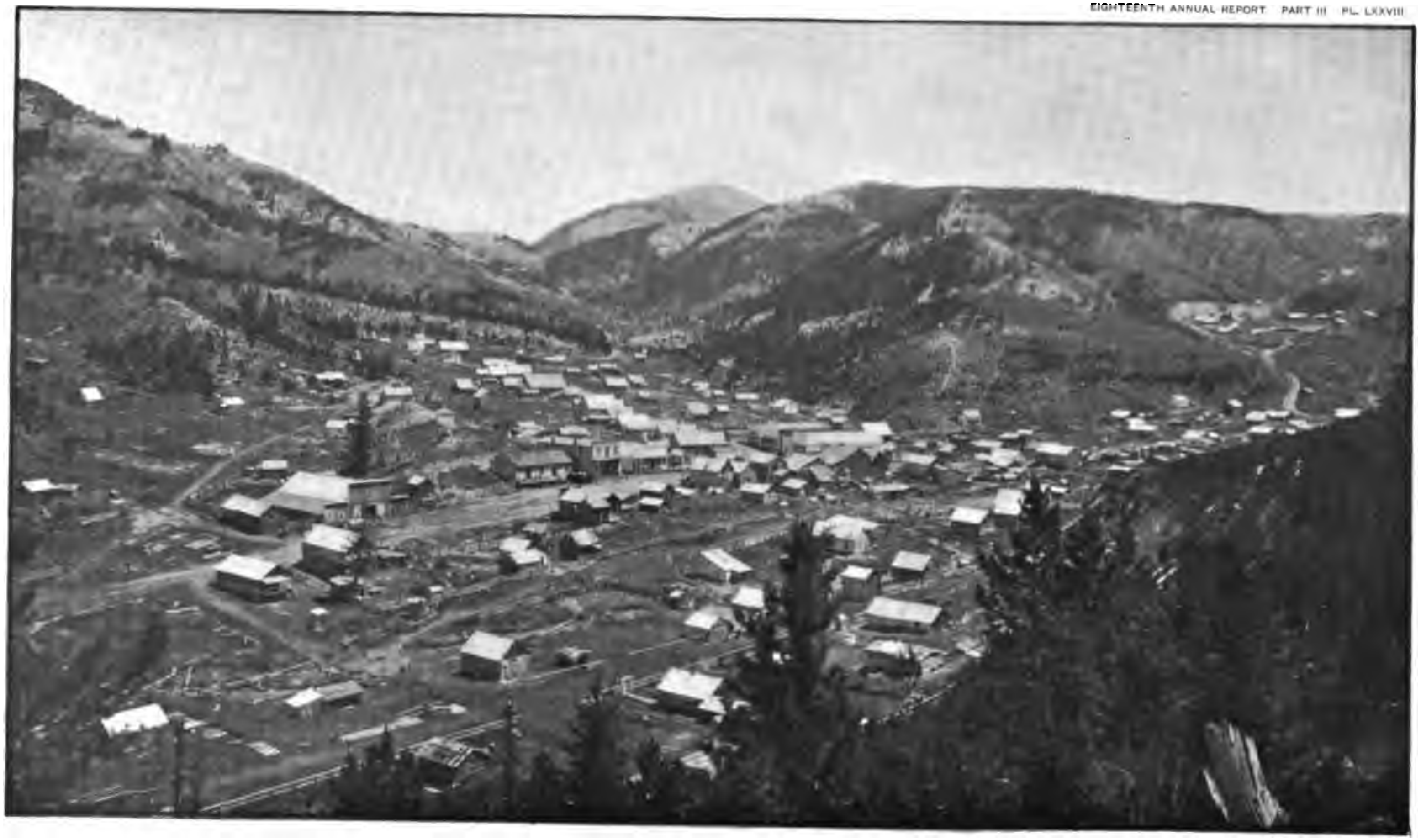


FIG. 43.—Sketch of Sheep Mountain (on left) and Pekay Peak, seen from slopes of Maiden Peak.



MAiDEN, FROM THE WEST.

The north slopes of upper Warm Spring Valley present a highly accidented surface, and are cut by a series of narrow, deeply trenched V-shaped gulches, separated generally by spurs having narrow crests alternating with prominent shoulders. They are composed of the Cretaceous beds in their regular stratigraphic order, but tilted to the north and greatly thickened and swollen by intrusive sheets of quartz-bearing porphyry, as shown in the cross section C–C of Pl. LXXXII. The porphyry forms the knobs, or shoulders, while the softer shales retreat, forming saddles on the spurs. In following down the crest of the spurs from Maiden Peak to the town below, as many as twelve of these sheets have been counted, of varying thickness. It would appear as if the sheets did not remain everywhere of the same thickness, but swelled out into thicker lenticular masses in places; but this is difficult to decide positively, as the Cretaceous shales almost never show any outcrops, but weather down to a soft soil, which the porphyry slide-rock easily covers. In the side gulches the talus slides of several sheets may coalesce, so that a large intrusive mass appears to be present. The sandstones of the Dakota group are most useful in this connection; they show the relations of the sedimentary beds, and that they are dipping northeast or normally away from the Alpine dome. It is possible that several of these sheets may run into one thicker one, but, for the reasons given above, this can not be positively determined. The sheets appear to have produced very little action in the shales; the latter are, directly at the contact, somewhat indurated, but at the distance of a few feet the effect is lost. The sandstones do not appear changed at all. The intrusive mass of Maiden Peak has indurated the black Benton shales to a greater extent, but considering the size of the intrusion the effect seems small.

The highest Cretaceous beds shown in this ridge are the Benton shales, which are best seen in several exposures near the heads of the gulches and on the divide west of Maiden Peak. At the latter place a cut bank exposes a considerable thickness of them. At this point they are somewhat indurated and of a dove color. One layer contains fish scales; no other fossils have been found in them. In these shale areas in the gulches springs break out, and each gulch contains a little rivulet of cold water.

The character of these long, narrow spurs running down into the valley, with the occasional porphyry knobs on them, is well shown in Pl. LXXVII, on the right-hand side. The one of these knobs highest up in the valley is that which forms a little conical peak just above the town of Maiden (see fig. 43); it is below of porphyry, then sandstone, and lastly porphyry to the top. On the side toward Gold Hill it is separated from the latter by a very low-cut saddle composed of shale. It is seen in Pl. LXXVIII, just back of the town and a little to the right of the middle of the view; the saddle mentioned is seen on its right. Between the small conical peak and Gold Hill in the background lies a little basin, scored by gulches, back of the Maginnis mill.

The variety of porphyry composing the sheets which have been described is the usual type—a rotted, altered porphyry of pale-brownish to white or pale rusty-red color, showing occasional quartzes of the size of coarse shot embedded in it. The rusty colors are due to the decay of some former iron-bearing mineral, such as hornblende or pyroxene. The variety of the intrusion of Gold Hill is similar, but in places varies somewhat, the quartzes disappearing and large feldspars, up to one inch long, occurring as phenocrysts. They are well crystallized and weather out of the rock, so that specimens as perfect as crystallographic models, showing also Carlsbad and Manebacher twinning, may be picked up in the gravelly débris. They are most numerous on the slopes of Maiden Peak.

Phonolite-porphyry.—On the north side of Warm Spring Valley, below the town of Maiden, is a large, well-defined intrusive area of a variety of porphyry of phonolitic habit. It forms one of the spurs known as Cemetery Hill. The outcrops of the porphyry are extremely large, heavy, and massive, and where broken down the rock produces masses of huge bowlders. Everywhere it is surrounded by soft shales, and no definite relation of the igneous rock to the stratified beds could be determined; it may be a broken-down sheet or an intrusion of dike-like or stock-like form. Toward the northeast the boundaries of the mass narrow, and eventually one sees only occasional bowlder-like outcrops leading to the divide. On the divide itself (between Warm Springs and North Fork creeks) are two well-defined dikes of the same rock, which pass down the slope toward the North Fork, and one occurs west of here in the edge of the steep grass-covered slope leading down into Warm Spring Creek.

The rock found in Cemetery Hill and in the Smelter Gulch is of a greenish color, with large white feldspars abundantly scattered through it. A close inspection shows small, glittering, black prisms of pyroxene, or dark, bronzy plates of mica; these minerals are embedded in a greenish groundmass. The rock is a variety of the phonolite family, and might be called an ægirite-syenite-porphyry. The other dikes mentioned are of similar character, but much denser in grain and of dark-greenish color. They are a variety of phonolite, and might be properly termed tinguaite-porphyry. They are described in Chapter V, p. 567.

NORTH FORK OF WARM SPRING CREEK.

Standing on the north slopes of Maiden Creek and looking down into the valley of the North Fork of Warm Spring Creek, one sees an open, basin-like valley with a rather flat floor descending toward the west. On all sides this valley appears shut in by mountain walls with sharply descending slopes. Sometimes these steep mountain sides are open and covered with grass, sometimes with dense and crowded growths of young pines; often they show long, brown slides of porphyry talus.

The valley bottom alternates with open fields or groves of tall timber. Many springs run down from different sides, their courses marked by lines of trees or tangled thickets of willow and black alder. The most striking feature in its scenery is the huge mass of tall, red-brown crags which rise precipitously from its slopes toward Judith Peak, and which are known as the "Chimneys." They form one side of a stock of granite-porphyry to be described later. From nearly every point this mass of huge crags dominates the valley.

The geologic structure of the North Fork Valley is simple. It consists of a mass of soft Cretaceous beds surrounded on nearly all sides by intrusions of porphyry. Erosion has cut away the soft shales of the Cretaceous forming the valley floor, while the more resistant masses of porphyry are left standing as its steep walls.

The spur between the North Fork and the main stream consists, as noted before, of black Benton shale, which is exposed at a low point or saddle west of Maiden Peak. A rude wagon trail from Maiden to the North Fork Valley and the Lincoln ranch crosses the ridge at this point. West of this locality porphyry is again found on the divide, and it continues to the end of the spur, which is cut by two narrow, transverse dikes of phonolite-porphyry of the tinguaite variety. On the north side this porphyry mass descends in a long, steep slope of porphyry talus, thickly covered with young pine, to the creek below. The igneous rock crosses the stream, and for half a mile or so the North Fork, after leaving the open, upper valley, runs down through a small, narrow canyon cut in it. The stream is a rather small, swift-running brook, whose clear pools contain small trout. On its south and west slopes this porphyry mass descends in talus slides and has large areas of broken-down rock in place; the outcrops are so cracked and broken that it is difficult to recognize them as such. Toward the south a long tongue protrudes from the mass and reaches nearly to the highroad passing up Warm Spring Creek. So far as can be told, this mass is not intrusive in the Cretaceous beds as a laccolith or sheet, but is erupted through them as a stock or chimney, the difficulty in the determination being due to lack of exposures of the soft Cretaceous beds with which it is in contact.

South of this porphyry, at the forks of the little branch of Warm Spring Creek and but a short distance from the contact, coal has been mined. It does not appear to be of good quality or favorably suited for working at this place, but its presence is of importance in locating a definite horizon of the Cretaceous—the Kootanie.

The central part of the valley of the North Fork contains a number of porphyry knobs which appear to be exposures of sheets. No definite outcrops of the Cretaceous are seen, but the disposition of the beds, with their frequent terrace-like aspect, shows clearly by the topography that they are of Cretaceous character.

At the eastern head of the valley the upper slopes are of porphyry débris from the intrusive masses of Maiden and Big Grassy peaks, which are separated by a low divide containing Cretaceous sandstone. On the east and north the entire upper slopes are of porphyry, cut in the great mass of which Big Grassy and Judith peaks are a part. Near the edges of this mass, and especially near the Chimneys, the Cretaceous shales are somewhat indurated by the igneous rock, but still fail to give good exposures. One feature of the Cretaceous beds in this valley is the frequency with which masses of the soft shales have slipped along the slopes, producing little cornices or shelves.

The northern branches of the stream rise in the grassy upland meadows and basins cut in the porphyry between Judith and Porphyry peaks, one of which, the most westerly, flows down past Porphyry Peak, after leaving the mountain meadows, through a steep ravine full of porphyry talus, and, passing a long spur, joins the main stream as it issues from its canyon. This long spur, which is wooded with open groves of large timber, is everywhere covered with bowlders and broken-down masses of a light-colored syenite-porphyry, sprinkled with large feldspar phenocrysts. Cretaceous beds were not actually found exposed on this spur, but the topography clearly indicates their presence. After this large branch joins it, the North Fork flows through a pleasant, open valley, passing at times through heavy copses in the bottom, or the fertile meadows of the Dougherty and other ranches, to join the main stream of Warm Spring Creek.

BALD BUTTE AND THE WARM SPRING CREEK DOME.

After the North Fork joins the main Warm Spring Creek the stream flows through a bushy, alluvial bottom, having a number of excellent ranches on either side, the waters of the creek and of the side branches that come in being used for irrigation. These small streams head back in springs rising in the Cretaceous foothills and rarely run dry.

The North Fork joins the stream at the point where the coal sandstone crosses. The latter forms a low ridge, but on the south side of the creek, just back of the Wocasek ranch, it rises into a high, dark, wooded hill of the usual type. Below this, to the southwest, the country is open, level, and ranched, belonging in part to the New Years Creek Basin, heretofore described. On the north side of Warm Spring Creek, between it and the North Fork and west of the latter, there is a long ridge of Cretaceous beds running down to the valley, which appears to be a strike ridge from the attitude of the beds, composed chiefly of the Dakota, trending southwest and dipping about 20° NW.

Northwest of this spur the country is much broken, cut into numbers of narrow gulches, usually open and grassy, but with occasional patches of pines. There are several ranches here. In this area there are a number of intruded sheets of porphyry, some of which form shoulders and points, and the topography is precisely similar in its main features to the shale and porphyry slopes of the hillsides north of the town of Maiden, already described, and these features are due to a similar intrusion of sheets of porphyry into Dakota beds. Several excellent exposures of the sandstones in this little group of hills are to be found. They gradually rise to a high, flat-topped ridge forming an open, grassy divide between the North Fork and the heads of Deer Creek, which is crossed by a wagon trail. This ridge passes into a craggy ledge of porphyry which runs toward the northwest and finally culminates in Bald Butte.

Bald Butte is a high, conical hill composed entirely of porphyry and covered with plates of the broken rock. It is quite bare and devoid of vegetation, a fact which has evidently suggested its name. Standing thus elevated and dominating all the open country to the north and west below, it is a very conspicuous object and was evidently one of the landmarks of the old freighting road from the Missouri River to Helena, which passed along the north side of the mountains. It is mentioned under the same name in the report of the Ludlow expedition in 1875 by Dana and Grinnell (see p. 471).

The structural relations of the sedimentary beds to this mass of porphyry are very difficult to ascertain, since no exposures of them are to be seen in connection with it. The porphyry may be intruded directly through the strata without reference to bedding, or it may possibly be the remnant of a thick lenticular laccolithic mass. The former supposition seems more probable. The rock composing it is generally altered, but where found in fresh exposures it is seen to be a syenite-porphyry of a pale-buff to gray color, with numerous small, indistinct, white feldspars and many small black prisms of hornblende embedded in it.

The Dakota beds, in which the numerous sheets of porphyry mentioned above have been intruded, appear to dip away from the small anticlinal dome which has been cut through by Warm Spring Creek. In following down the main road along the stream, when opposite the porphyry hills to the northwest above, one passes over the red clays of the Dakota formation and soon close under a heavy mass of tilted sandstones. Beyond this the road forks, one branch going toward the right, over to Deer and Armell creeks, while the other keeps on down Warm Spring Creek and is the highroad to Lewistown. At this point there is an area of hilly country through which Warm Spring Creek cuts its way. This tract is due to the doming up of the strata by a laccolithic intrusion, as already mentioned, and its dissection by Warm Spring Creek affords excellent means for its study. As shown on the map, the upraise has brought the Kootanie to the surface, and within it the Jurassic and top of the Carboniferous formations. The intrusion of the porphyry has taken place in the lower shale beds of the Jurassic, but below there must be concealed another one which has brought up the Carboniferous.

The heavy sandstone mentioned above is that just over the coal; at the point indicated it dips sharply northeast and forms a high ridge. The outcrop is extremely massive, weathering the usual light-buff and pink colors, and it passes northward over a hill, where it is cut through by a little spring stream. At this point the coal seam under it has been prospected. It passes up the side of the ravine and emerges on an open, rolling country, the strike of the outcrop bending to the west. On this table-land the outcrop forms no prominent ridge, but is easily traced by its débris. The road to Armell Creek crosses it. East and north—i. e., above the sandstone—appear the red clays and sandstones of the Dakota formation. The outcrop of the coal sandstone gradually bends southward, again assuming its ridge-like character and passing down a ravine, of which it forms one side, and reaching Warm Spring Creek about 1½ or 2 miles below the point where it left that stream. Where the creek cuts across it there is an alluvial flat, and the outcrop is here for a short distance lost, but on the other side of the creek it immediately reappears, assumes its character of a high wooded ridge, and, running eastward with a slight southerly curve, forms a continuous rampart or bluff along the south side of Warm Spring Creek, until eventually it disappears in crossing the stream to the point where it was originally met. This long ridge is cut through at one place by New Years Creek, and at a point perhaps a half mile west of that stream a gulch or ravine has been cut back in it, and here the coal has been mined and considerable work done. This is mentioned later in the economic chapter (p. 616). The thickness of the sandstone bluff over the coal is about 30 feet at this point.

From what has been said it will be seen that the outcrops of the coal sandstone form a rude circle, over a mile in diameter, through which Warm Spring Creek has cut its way. Inside of this circle and stratigraphically under it are the beds of the Jurassic formation. The limestones are well exposed at the forks of the road, and their outcrops may be traced up the hill toward the coal sandstone. They exhibit the usual section, and the thinly bedded limestones contain ostreas and gryphæas. The little stream descending from Bald Butte has trenched a short, narrow ravine through these limestones, and on the west side of it they rise in a wooded hill, domed up by the intrusion of porphyry. The outcrops may be traced up the hill and out on the table-land to the north. Inside of the Jurassic and on the north side of the stream the intrusion of porphyry forms a high hill, which rises probably about 300 feet above the stream, its steep front extending almost a mile. The highroad runs directly at its base. It is cut into on this south front by one prominent and several minor gulches, and the crest line at the top is undulating. On its face, fronting the stream, there are sedimentary beds below, then shales and calcareous sandstones, with porphyry above them to the crest. In the main gulch outcrops of altered argillaceous limestone occur, dipping gently back into the hill. At the top fossiliferous Jurassic limestones are found, and an inspection on the north side—that is, the back or upper surface of the laccolith—shows that the sedimentary cover is, geologically speaking, just on the point of being stripped off. In most places it is very thin, and in some the porphyry is exposed nearly down to the table-land below, where the upward-facing outcrop of the Jurassic beds, with a sharp dip to the north, is clearly seen, while a little farther west it suddenly ascends the hill again nearly to its crest, covering up the porphyry. The main mass of the sediments, however, produces a curving gulch, which descends to Warm Spring. These relations are shown in fig. 45, while a north-south section is given in fig. 44. From this it is evident that Warm Spring Creek has cut away nearly one-half of the laccolith and its cover, and this portion is now replaced by a narrow alluvial flat. Since Warm Spring Creek has not been deflected by this dome and forced to go around it, we must conclude that it is an antecedent drainage.

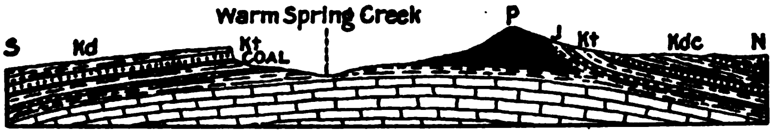


FIG. 44.—North-south section through the Warm Spring anticline. Kd, Dakota sandstone; Kt, Kootanie sandstones and coal; P, porphyry; J, Jurassic; Kdc, Dakota and Colorado groups.

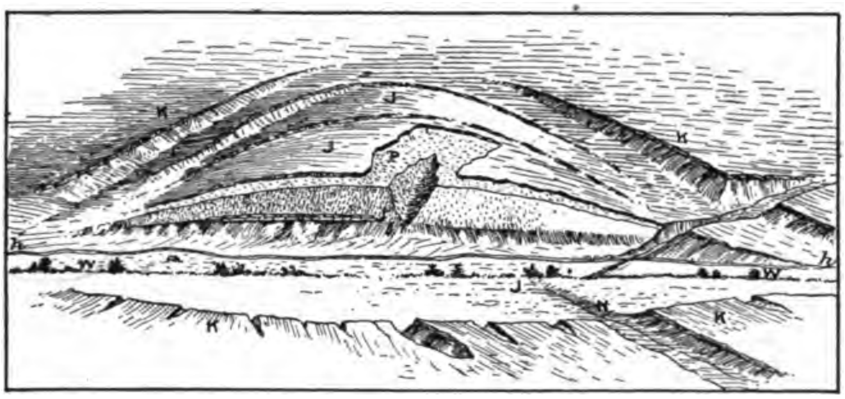


FIG. 45.—Stereographic sketch of Warm Spring anticline and laccolith. Looking north. J, Jurassic beds and outcrops; K, Cretaceous beds and outcrops; P, porphyry of laccolith, dotted; W, Warm Spring Creek; N, New Years Creek; h, road.

The rock of this laccolith is a very fine, dense, quartz-bearing porphyry of the usual type, much altered, of light-buff to brownish color, and generally broken into small, chippy fragments or weathered to a gravelly débris. It does not present any bold or prominent outcrops.

There does not appear to be any extensive contact metamorphism produced by the intrusion. In the main gulch, facing Warm Spring

Creek, the lowest sediments exposed are dark, chippy shales, much indurated, and it is believed that these are the soft greenish shales of the Jurassic, which form so many stream courses or are weathered so commonly into saddles on the ridges throughout the mountains. The lowest beds exposed in the anticline are believed to be those at the top of the Carboniferous; they are the yellow, earthy, arenaceous beds which form the top of the section and are exposed at one point on the bank of Warm Spring Creek, where a ditch-cutting begins.

HEADS OF DEER CREEK.

The western heads of this stream rise in a hilly country north of Bald Butte and Porphyry Peak, which is formed of Cretaceous beds cut into by a number of small gulches that afford but few exposures of the rocks, grassy hill-slopes, wooded ravines, and meadows everywhere prevailing. As in the valley of the North Fork, heretofore described, the porphyry either comes down in a mass of slide-rock from the upper elevations to meet the grassy Cretaceous slopes, or, if the slope is not too pronounced, forms of itself a grassy upland with gravelly soil. Thus in general, while the boundaries of the porphyry are easily traced, its structural relations to the Cretaceous beds are not clearly defined.

In the branch of Deer Creek which heads directly north of Porphyry Peak, near the point where the forks come together, less than a mile northwest of Porphyry Peak, the stream trenches a deep ravine, which is seen to be cut in black shales, probably the Benton group. Gray Cretaceous sandstones are found in other gulches, and red clays are seen in the valley below. What the structure of this valley is can only be surmised, but general considerations lead to the belief that the porphyry bears no definite relation to the structure of the sediments, but is intruded directly through them.

Deer Creek dome.—Somewhat farther to the north, however, there is no question as to the attitude and structure of the Cretaceous beds; they are elevated into an anticlinal dome, that must undoubtedly represent a concealed laccolith of porphyry of which as yet no part has been brought to the surface by erosion. The distance across the surface of the dome is somewhat over a mile. It appears to be chiefly the Dakota formation which is exposed, though the Kootanie probably comes to the surface in the center, and is so shown on the map. The structure is clearly shown by the sandstones of the Dakota, which form a series of revet hills disposed in concentric circles, each hill with an abrupt face turned inward and showing a section of the strata, but having a long slope to the outer side, where the backs of the beds are seen. In other words, each hill is a monocline, dipping away from a common center. The red clays of the Dakota are prominent on the backs of the hills. The west fork of Deer Creek is deflected by this anticline and flows around it in the moatlike or encircling valley. From the high porphyry point southeast of it the structure of the anticline is clearly revealed and a most excellent bird's-eye view of it obtained. This porphyry itself, which is a part of the great Judith Peak mass, appears to have been intruded through the strata without regard to the anticline and to have cut into its southeast limb. It is in contact with sandstones which form a sort of terrace around the porphyry at this point, and these sandstones dip inward toward the porphyry, or rather outward and normally away from the center of the anticline without regard to the porphyry, with which they come into contact. On the south the strike is northeast, changing to north as one advances northward along the front face of the porphyry. A number of small drainage channels coming down cut through the sandstones, forming small gateways and giving good exposures. One of these streams, as shown on the map, cuts directly through the center of the anticline. The present road from Warm Spring Creek to Armell Creek passes along the west and north sides of this domed anticline, and from it excellent views of the little revet hills and upturned sandstones of the Dakota formation may be obtained.

East fork of Deer Creek.—The porphyry mentioned above is a protrusion to the northward of an apophysis or tongue-like mass from the great Judith Peak mass, to be described later. At this point it rises in a hill, descending on the north side in craggy, precipitous masses to a saddle, whence it again rises a little, to the crest of a spur which descends northward into the open country, the spur being wooded and covered with porphyry débris. On the east side of this spur there is a deep ravine full of springs rising in a bottom made of step-like masses of black shales, probably of the Benton group. Above, to the south, the porphyry forms a sort of terrace, and as soon as its edge is reached the descent through the shales is rapid. This ravine joins a larger one, which seems to carry the main head of the stream and is cut back into the porphyry, forming a wooded gulch, which reaches back and upward to the mountain meadows on the porphyry northwest of Judith Peak.

On the east side of the stream limestones appear on the hillside, and a little dry cross-gulch, not shown on the map, which comes in from the northwest, gives an excellent exposure of them. They rise along the hillside until, eventually, at the point where they cease, they form a high and rather precipitous crag, which marks their extension to the south. At this point they are in contact with the porphyry and are whitened and bleached by contact metamorphism. The strike here is nearly north and south, the dip west. The wooded slopes above are all of porphyry. This mass of limestone, shown by exposures elsewhere to be of the upper Carboniferous, is, in its total area, considerably over half a mile across, and the exposed portion has the shape of a tilted spoon. Around the upper contact of limestone and porphyry the strike is found to change to nearly east and west, the dip being north. Only at its southern point, mentioned above, does the limestone show any noticeable contact alteration.

Several small dry ravines have been cut into this limestone, and form head branches of the east fork of Deer Creek. One of these shows on each side of the ravine long exposures of the massive Carboniferous as a continuous ledge. Each of the ridges between these ravines invariably shows a considerable mass of porphyry intruded above the Carboniferous, and beyond this appear the beds of the Jurassic, sharply tilted back, and lastly the Cretaceous, whereupon the spur ends in the open country. It thus appears that the great block of Carboniferous which has been torn up and bent back by the porphyry intrusion is also completely surrounded by porphyry. The porphyry, in advancing on either side and intruding between the Carboniferous and Jurassic beds, has lifted the latter and thrust them away from the Carboniferous. These relations are shown in the cross section, fig. 46.

The end of this exposure of the Jurassic formation appears to round into the gulch on the west, where it dies out under the edge of the advancing Cretaceous. On the north and east the Jurassic beds are carried across the end of each spur and there turn toward the south, where, as usual, they form a strike gulch, and do not appear until they reach the spur that separates this drainage area from that of West Armell Creek. The porphyry lies inside of this Jurassic series and forms the crest of the spur which advances back of the limestone block to a high point, shown on the map. Beyond and stratigraphically above the Jurassic the Cretaceous follows it round, but on the northeast side there is a heavy intrusion of porphyry in these Cretaceous beds, which has been eroded into two sharp conical hills, shown on the map, with lesser crags of porphyry connecting them. They are held to be the uneroded part of a tilted laccolithic mass intruded in the Cretaceous at this point. The sandstones and shales into which it has been intruded show considerable induration and hardening by contact metamorphism. The Cretaceous beds of the open country to the north are weathered down and show no outcrops, but about a mile due north of the porphyry hill last mentioned there is a considerable amount of

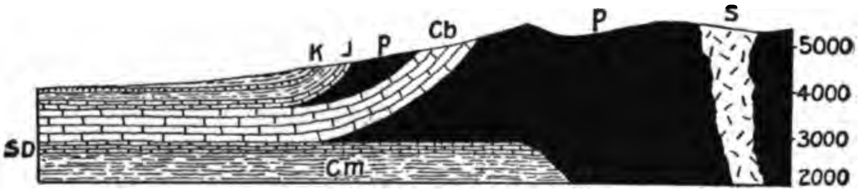


FIG. 46.—Section northwest and southeast through foothills and mountain summit 2 miles northwest of Judith Peak. K, Cretaceous; J, Jurassic; Cb, Carboniferous limestones; SD, Siluro-Devonian limestones; Cm, Cambrian rocks; P, porphyry; S, syenite. Figures represent heights above sea level.

broken-down porphyry, in heaps and bowlders, which would appear to be the remnant of a sheet intruded in soft Cretaceous beds.

The porphyry which composes all the masses at the head of Deer Creek, while usually much altered, is by no means so thoroughly decomposed as most of the quartz-bearing porphyries which have been described as occurring in these mountains. It is of a reddish to brownish-gray color and in a fine base contains numerous large feldspar phenocrysts and smaller ones of black hornblende or pyroxene. It may be called a syenite-porphyry. It would be classified under the Big Grassy type described in Chapter V (p. 564).

WEST ARMELL CREEK.

The mass of porphyry mentioned above as forming the two little hills is stripped of its Cretaceous cover at its most easterly point until West Armell Creek cuts past it, the igneous rock reaching to the stream. Above this mass is a gulch cut in Cretaceous shales, with a fine spring in the lower end of it. Above, in this gulch, the Jurassic appears on the little spurs, as seen on the map, the porphyry still above it. It appears to take a very sharp bend here, and the gulch running down to the West Armell is cut in it.

The main stream itself, before cutting through the Cretaceous, has a well-defined canyon in Carboniferous limestones; it is the second largest and longest canyon in the mountains, that of Maiden Gulch being first. Above these limestones comes the porphyry of the Judith Peak area, in which the head forks of the stream have cut some large amphitheaters, described later in connection with this porphyry mass. A general survey through the canyon and from the hills on either side and the mountains above shows that in the main there is here another heavy block of tilted limestone, quite similar in its chief characters to that on Deer Creek, described heretofore, but of three or four times the area. Observation shows, further, that this mass has its edges bent up near the porphyry intrusion; that it then flattens somewhat in the center, owing to intruded masses of porphyry under it, and that finally, on its northern boundary, it dips down sharply under the sediments above it. How thick the mass of limestone here exposed is it is difficult to say; but the part that is most prominent is the heavy, massive series near the top of the Carboniferous, and there must be several hundred feet of these limestones exposed. On the east side of Armell Creek these beds are cut through by a number of dry gulches which come down from the porphyry of the long ridge above and pass into the main canyon through gateways of the limestone formed by imposing crags. These limestones are somewhat altered and mineralized, and in one exposure above the forks of the creek was the Cave mine. (See p. 610.) On the other side of Armell Creek—the southwest side—the limestone rises in several spurs which run back toward Judith Peak. On one of these spurs, near the contact with the main porphyry, an intrusive sheet is injected, while on the next spur east, between the forks of the creek, there is an intrusive sheet of syenite-porphyry about 15 feet in thickness, and this is cut by a dike of phonolite-porphyry. Nearer the forks of the creek, below the occurrence mentioned, another dike of this phonolite-porphyry penetrates the limestone; by alteration, however, it has been leached of its iron contents and changed to a light-colored clay, whose nature would not be recognized if the feldspar phenocrysts and the structure, being perfectly preserved, did not reveal its identity. It has been prospected for gold, which it carries in small quantity.

In the main canyon itself a considerable mass of porphyry is exposed on the south side of the stream at and below the forks. It is covered with a heavy growth of timber, and is easily distinguished in this way from the more open limestone areas above and around it. It underlies the massive Carboniferous and is evidently the top portion of the mass which it conceals.

Ascending the stream channel from the open country, one finds the following succession of exposed beds:

Beds exposed in West Armell Canyon.

No.

13. Black shales, containing a heavy intruded sheet of porphyritic tinguaite (phonolite-porphyry), about 10 to 12 feet thick, and carrying numerous immense feldspar phenocrysts, some being 4 by 2 by 1 inches; weathers reddish, and is seen only on east side of stream. Black shales, believed to be the Benton group, baked and indurated near the contact.
12. Interval marked by prominent gulch on both sides of stream.
11. Shales, with intruded sheet of porphyritic phonolite (tinguaite), which is about 4 feet thick.
10. Interval marked by a little gulch.
9. Outcrops of a sandstone, weathering to bright-red soil.
8. Interval of about 75 feet.
7 Sandstones, perhaps 100 feet in thickness, indurated at bottom, but passing to a sugary character at top, of a light-gray color, but weathering buff.
6. Series of shaly, argillaceous, calcareous beds, considerably altered, but not so much as No. 4.
5. Dove-gray limestones, which are believed to be Jurassic, though no fossils could be found in them.
4. Shaly beds, baked to tough green and black adinoles, containing a layer of impure marble about 1 foot thick, probably Jurassic shales.
3. Porphyry sheet intruded, about 300 feet thick, rising into hills on either side of the stream.
2. Massive Carboniferous limestones, which extend a long distance and in which the canyon is chiefly cut.
1. Porphyry under the massive Carboniferous.

No positive definite section is attainable, but the above gives an idea of the succession of the beds and their character as seen. The porphyry is the usual altered type. It is noticeable that both the porphyry and the phonolite have metamorphosed the sediments above them much more than those below.

One other feature of West Armell Creek deserves notice, and that is the deposit of limonite which occurs on the west fork of the stream, near its contact with the porphyry of the main mass. The deposit is described in the last chapter (p. 614). West Armell Creek is charged with iron salts, which are deposited as a whitish to pale-brown carbonate in its bed.

Below the canyon the creek broadens out and ranches appear in it. An exposure of the modern stream deposits near the mouth of the canyon shows about 15 feet of well-bedded clays, gravels, etc., very red from iron ore. In one place they have been washed for gold with some success.

SPOTTED HORSE GULCH.

Beyond the smoothly modeled slopes of porphyry and Cretaceous shales which are seen on the left in Pl. LXXVIII is the beautiful mountain park at the head of Spotted Horse Gulch, which lies between Maiden, Big Grassy, and Crystal peaks. It shows an evenly floored basin, whose sides gradually rise in long, smooth slopes to the divides between the peaks mentioned. Toward the south the basin begins to slope down more rapidly, and between Crystal Peak and Gold Hill it assumes the character of a deep, narrow valley, which passes into a deeply cut V-shaped ravine that, turning more and more to the south, ends in Maiden Canyon.

In the upland basin, at the head, under the slopes of Big Grassy and Maiden peaks, rise many springs, which flow down in small, cold rivulets. In the early summer the long, moist slopes are richly decked with a wild luxuriance of grasses and many-colored, delicate wild flowers, or interrupted here and there by clumps and groves of dark-green pines. All is fresh and verdant. It is a natural garden whose pleasing features are in strong contrast to the wide horizons of arid plains country whose heat-hazed distances are seen from any point on the basin's rim.

A wagon trail leads into this park from the town of Maiden, and others pass into and down Collar and Spotted Horse gulches. They are not impassable, which is the best that can be said for them.

The upper portion of this basin is cut entirely in the porphyry of the Gold Hill-Maiden Peak intrusive mass. There are no exposures of this porphyry to be seen except on the south slopes of Maiden Peak. It is everywhere weathered down into a soft, reddish-brown, gravelly débris, which affords smooth slopes. On the divide between Big Grassy and Maiden peaks this uniformity of porphyry is interrupted by the occurrence of Cretaceous sandstones. Unfortunately, the outcrop is so broken down into débris that it affords little evidence of the relations of the porphyry to the sandstones. The latter continue up the slopes of Big Grassy Peak to an elevation of 150 feet above the lowest point on the divide. They are indurated almost to a quartzite, are of a clear-gray color, and are to be told from blocks of porphyry only by close inspection. Above them is the porphyry of Big Grassy Peak, the most southern extension of the great Judith Peak mass. These sandstones, with occasional outcrops in place, are to be traced in a broad band down to the divide between Crystal and Big Grassy peaks, where they pass down into Collar Gulch and become involved in the structure of the Crystal Peak uplift. Whether, on the divide between Maiden and Big Grassy peaks, these sandstones are merely lying on a continuous mass of porphyry passing from one peak to the

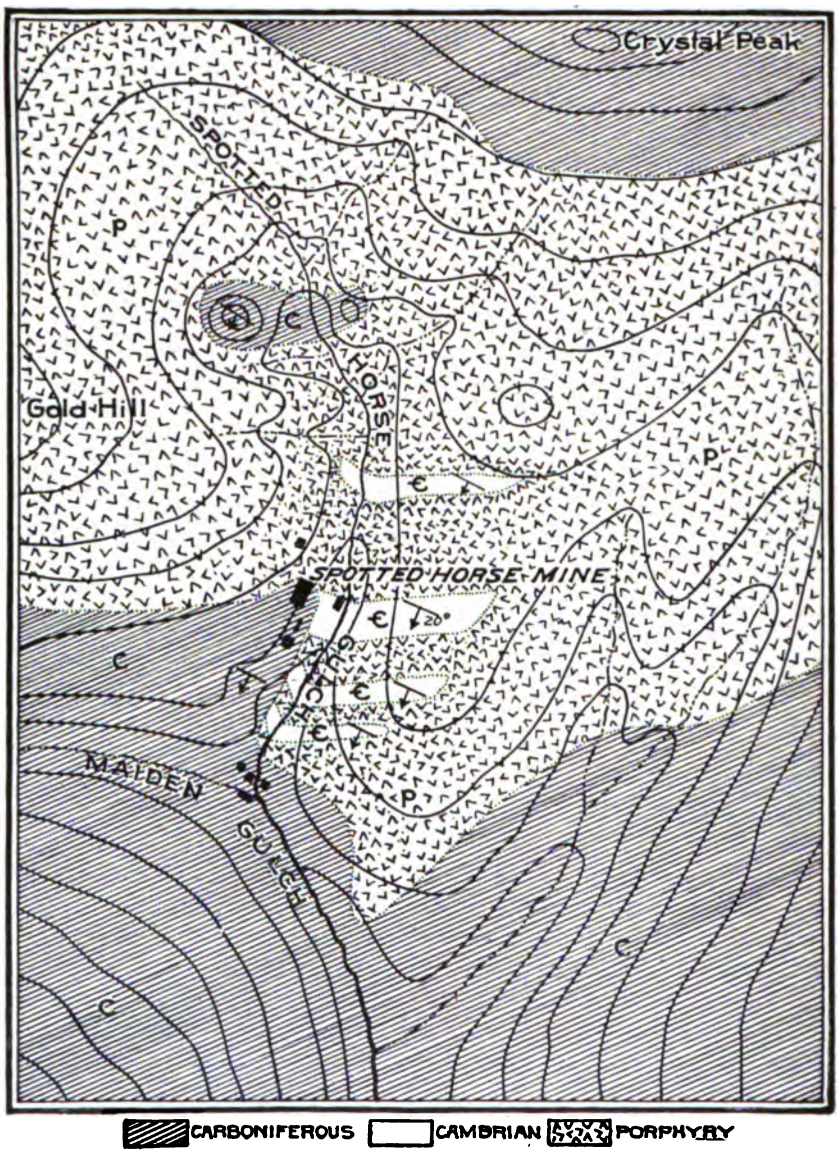


FIG. 47.—Geologic sketch map of Spotted Horse Gulch and vicinity.

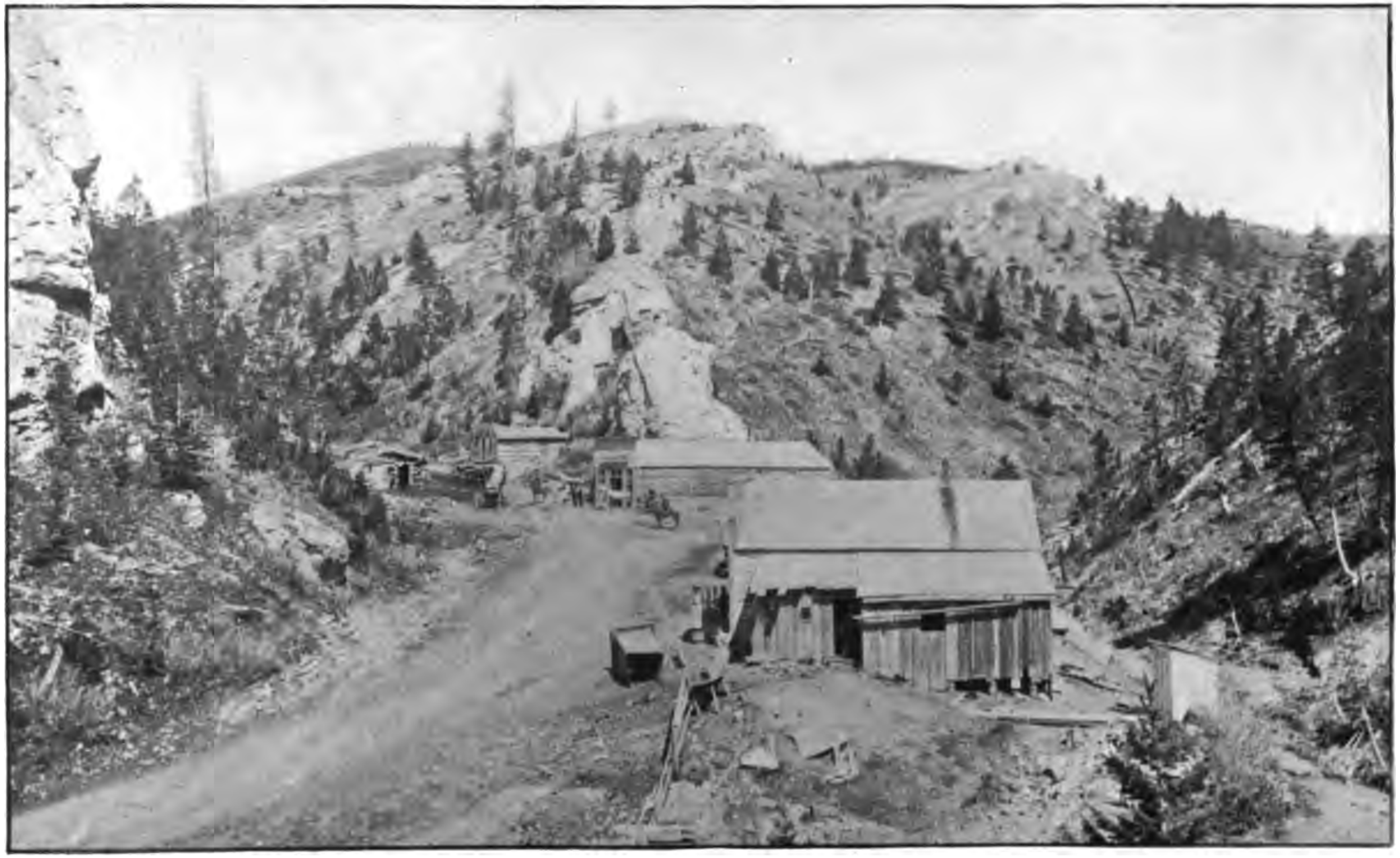
other, or whether they pass down under the Big Grassy porphyry, can not be certainly told, but the latter is believed to be the case.

In the southern portion of the park, not far from the Gold Hill-Maiden Peak divide, there is an isolated area of Cretaceous sandstones which are much baked and metamorphosed. They are believed to be merely a remnant of the former covering of the intrusive mass and to have no considerable thickness.

The porphyry of Gold Hill is much altered, and on the crest, to which a wagon trail leads from the divide just mentioned, there are found in it zones of alteration and apparently of crushing, in which the rock is reduced to an almost pure-white material resembling kaolin. In other places, as shown in the prospect pit at the very summit, it is considerably mineralized and filled with pyrite. This is said to carry a fair assay value. At the foot of the upland basin and at the point where it begins to rapidly descend into the gulch below, there stands the most conspicuous and noticeable object in it. This is a huge crag of massive Carboniferous limestone, which dominates the valley and was early known by the first miners in this region as "Collar Butte" (see fig. 47). There is a steep ascent on the west to its crest, but on the side of the stream it descends precipitously and the limestone appears again on the other side of the valley, where it also forms a smaller crag. It is entirely surrounded by porphyry and has a very steep dip to the south. The stream cutting through it shows a considerable thickness of limestone. It is much altered by contact metamorphism and is cavernous and somewhat mineralized. Though no fossils were found, it is undoubtedly massive Carboniferous. It appears to be a huge, isolated block torn off by the porphyry from the beds which either yet lie below or have been displaced by the intrusion of igneous matter. It has been somewhat prospected, but no considerable development work has been done in it, and whether it contains any promising leads we do not know.

Fig. 47 shows the relations of the igneous and sedimentary rocks in the vicinity of the Spotted Horse mine. The upper part of Spotted Horse Gulch is found to be cut entirely in porphyry to a point a short distance above the mine, where the channel is found cutting through a thin upturned block of much altered, conglomeratic Cambrian slates, about 10 feet in thickness. These are succeeded by porphyry, followed by more of the Cambrian slates, and farther down they are found to be of considerable thickness, but are intruded by sheets (blankets) of porphyry. There appear to be four of these intruded porphyry sheets, two perhaps 50 feet thick and two thin ones—about 10 feet. On the east side of the stream the Cambrian slates rise into the crest of the spur, and good exposures of them may be found. They dip southwest toward the end of the spur at 20°, and the upturned block ends toward the east nearly at the crest line of the spur, or a little below, toward the next drainage, the slates being cut off by the porphyry. On the Spotted Horse side the hill-slopes are mingled masses of débris from both the porphyry and the slates; on the other side of the gulch, the mine side, the slates ascend only a short distance, being covered with Carboniferous limestone. The latter, at the point where the mine is situated, is but a rather narrow wedge, being cut off by the porphyry above; but from this point the line of contact of the limestone and porphyry follows round Gold Hill nearly at a level to the divide above the Maginnis mine. The Spotted Horse mine is on the contact of the Gold Hill porphyry with the end of the limestone and just above the upstream end of the block of slates. The mine workings show that the contact between the porphyry and limestone has its plane or hade inclined inward toward the porphyry. Below the slates the line of contact between limestone and porphyry crosses the stream, and the limestones appear in the very end of the spur on the east side. Above them is a crag of porphyry on the hill, and the contact then runs along the front face of this spur end, facing into Maiden Gulch, its contact marked by porphyry crags, till at one point the porphyry comes down to the stream. From here it turns and runs northeast up the spur into the next gulch.

Where the limestone crosses the lower end of Spotted Horse Gulch fresh rock is exposed by the road cutting, where fairly well-preserved fossils of Lower Carboniferous aspect were obtained, such as a productus (probably *P. semireticulatus*), *Chonetes* sp., *Derbyia* sp., and a gastropod, possibly Euomphalus. The relations of the beds at this point, on the opposite side of the gulch and on the crest of the spur, show that, although the general dip and position of the limestone above the Cambrian slates are nearly conformable in structure, they are not conformable in stratigraphy, since apparently the whole of the Siluro-Devonian section is here wanting. The outer contacts of the porphyry mass with the limestones show that the former has been irruptive across the strata, and the probability is that the Cambrian slates represent a large block of that series which has been forcibly displaced and uplifted by the porphyry intrusion and whose normal structural relations to the surrounding strata have thus been violently ruptured. The porphyry itself, wherever it has been observed in contacts, as under Maiden Peak and in the next gulch east from the Spotted Horse, is always of this irruptive nature. In this next gulch its contact is marked at the spur end between the forks of the creek by a very massive crag exposure. The east fork cuts a deep ravine in it; turning northward it passes under Crystal Peak, where the long spur descending shows a great width of it, and from here it cuts off the beds until it meets the Cretaceous beds, previously mentioned, near the divide to Collar Creek. The mass thus outlined is of the shape of a rude triangle with sides about a mile and a half long. It is where this mass has come into contact with the Carboniferous beds that the largest mines in the district have been located—the Spotted Horse at one end of the contact and the Maginnis group at the other



SPOTTED HORSE GULCH.

end. It is believed that the area of contact between these two will become a favorable ground for exploration work in the future. Further details in regard to these mines will be found in the last chapter of this paper (p. 602). The porphyry has had a decided contact action on the limestones, bleaching them in places; but the action from hot solutions, vapors, etc., shown by the formation of purple and pink fluorite, quartz, etc., with deposition of the ores, is more marked, while a third set of changes, due to the decay from air and surface waters, has often masked many of the former.

In the Spotted Horse Gulch the Cambrian slates have been prospected, but apparently without success, as no development work has been done.

In regard to the character of the porphyry composing this large mass, details have already been given, and the rock is described in the chapter on the igneous rocks (p. 560).

CANYON OF MAIDEN CREEK.

The canyon of Maiden Creek, which, commencing at the divide above the town of Maiden, leads down into the open country on the southeast side of the mountains, is about 2½ miles along, and presents in this distance the most picturesque scenery to be found in the mountains. From the divide down to the point where the Spotted Horse Gulch opens into it the canyon is cut in Carboniferous limestones, descending the slopes from Sheep Mountain above. The bottom of the canyon is dry, whatever drainage there is passing underground, and its floor is occupied by the mail road. The grade is excellent and without break. The character of the canyon and the weathering of the Carboniferous limestones are seen in Pl. LXXIX, which is taken looking upward at the juncture of the Spotted Horse Gulch (to the right) with Maiden Canyon and the road turning the corner to the left. One of the buildings of the Spotted Horse mine is seen in the upper right-hand corner of the view.

At this point the water of the stream from the Spotted Horse Gulch comes into the canyon and flows for a considerable distance (depending on the season) before sinking in the limestone floor. The canyon itself widens and deepens. On the left are seen the crags which mark the limits of the porphyry; on the right all is Carboniferous limestone. Several gulches with dry, steep-descending sides open on the left down into the canyon.

The dip of the limestones at first near the mouth of the Spotted Horse is somewhat variable. They are warped, but approach horizontality; finally they dip downstream at more and more acute angles, until the massive bed near the top plunges downward at an angle of 40° and passes out of sight beneath the soft beds of the Jurassic and Cretaceous, which form the open country, producing an impressive gateway which ends the canyon and is shown in Pl.

LXXII. It is just above this that the most massive exposures are attained, and the pinnacles, crags, and buttresses of the light-gray rocks present a picture of quite imposing canyon walls, as illustrated in Pl. LXXI. It is here that the section of the Carboniferous given on pages 471–472 was made.

CRYSTAL PEAK ANTICLINE.

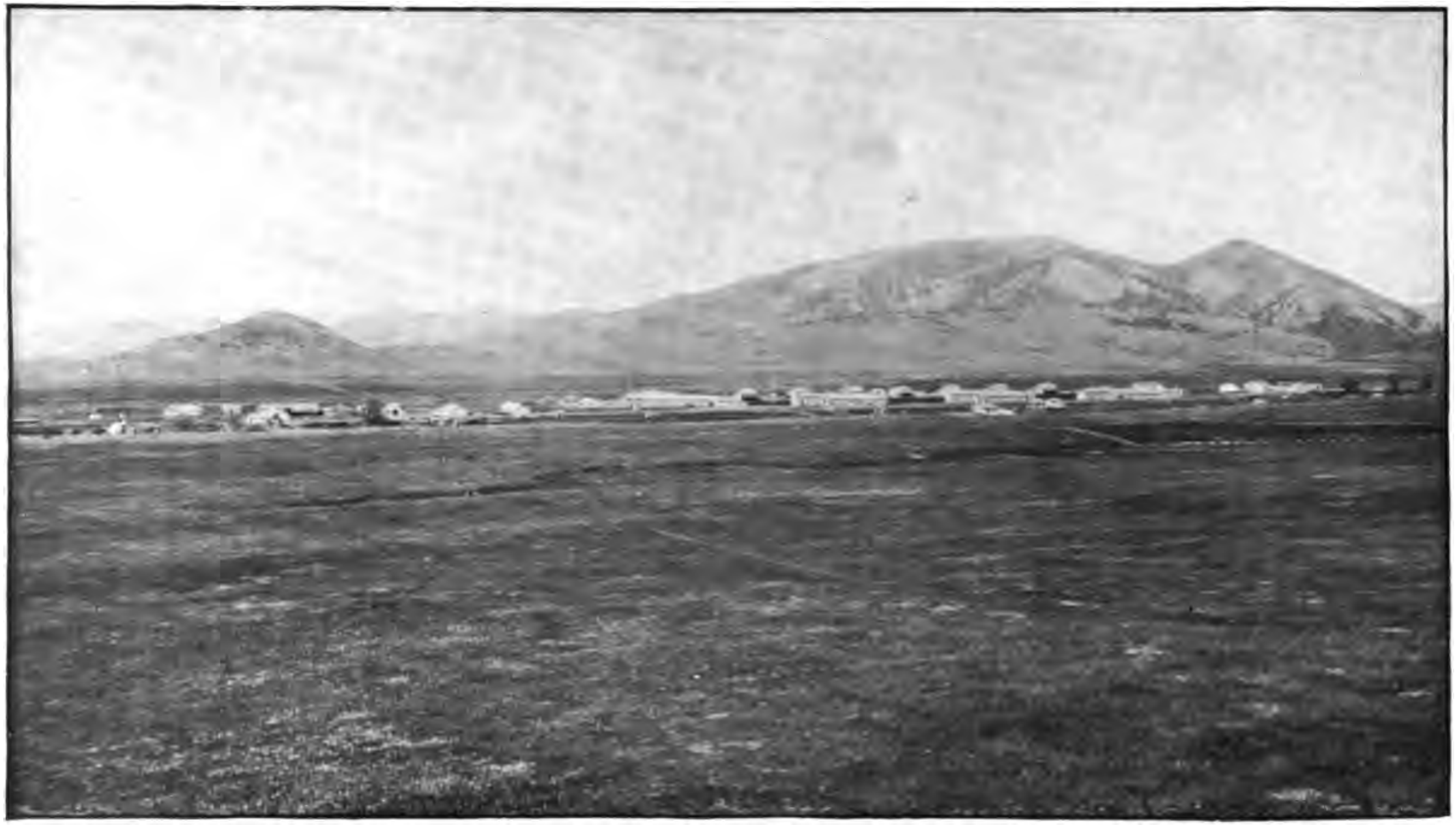
From any point in the park at the head of Spotted Horse Gulch Crystal Peak is prominent, and it is also clearly seen from the open country below, where it forms one end of a high mass of limestone. A little peak on the summit of this ridge, about a half mile south of Crystal Peak, is indicated on the map as a triangulation point. At Crystal Peak itself the limestones, which are upper Carboniferous, are nearly horizontal, with a dip of a few degrees to the south. A little below the summit, on the southwest side, is the Florence mine, located on the contact of the limestones with a porphyry dike. The outcroppings of the dike on the surface are so meager as to give little indication of its size and trend, while the mine workings which have cut it were not accessible when the locality was visited.

About 300 feet below, by aneroid, is the contact of the Gold Hill intrusive mass. On a spur to the north is the Pilgrim mine, also near the porphyry, but in limestone. A very steep road leads from the Collar Creek divide to the Florence mine, and Carboniferous fossils were found in the material thrown out in the road cutting, as mentioned on page 473.

A study of this limestone ridge, which commences at Crystal Peak and turns southward in a long spur down to the mouth of Maiden Gulch, shows that it is an anticlinal uplift of a domed character, the symmetry of the dome being destroyed along one side. Toward the northeast, east, and southeast the symmetry is well preserved, as is shown on the geologic map by the outlines of the various formations. The strike of the beds changes from that seen at the divide between Collar and Spotted Horse creeks until, at the mouth of Maiden Canyon, it has completed a half circle.

On Crystal Peak the dip is very slight, being near the top of the dome, but as one descends toward Collar Creek the dip increases to about 45°, and at this inclination the beds swing round the outer part of the circle.

On the western side the beds, as shown in Maiden Canyon, approach more nearly to the horizontal, and this side of the dome is sharply cut off by the intrusive of Gold Hill. Toward the west the anticline or dome impinges on the similar one of Alpine Creek. It is more irregular, however, in its central portion than the other domes so far described. All of the analogies show that a laccolith not yet uncovered has domed up the massive beds of the Carboniferous, just as at Flat Mountain. It would appear, however, that the intrusion of the



FORT MAGINNIS; JUDITH MOUNTAINS IN REAR.

laccolith was far less regular than in the cases so far described, and that it breaks through the cover on one side, giving rise to the irruptive Gold Hill-Maiden Peak mass. This, in all probability, was intrusive in the Cretaceous, and has been relieved of its cover only lately, speaking geologically.

Erosion has stripped the Crystal dome of its Cretaceous and Jurassic beds, and these have retreated back to the foothills and open country, where they form the usual revet hills with a steep inface. Thus the massive Carboniferous is left bare to outline the uplift, and, as usual, its white outcrops show the mountain slopes.

An excellent view of this dome from the east is seen in Pl. LXXX. The photograph is taken on the east side of the now abandoned Fort Maginnis, which is in the foreground. On the extreme right is seen the divide between Crystal and Big Grassy peaks; Crystal succeeds to the left, and then the long limestone ridge, the little point which is the highest next to Crystal being the triangulation point shown on the map. The white imbricating outcrops of the heavy limestone beds as they pass around the ridge are moderately well shown in the view. On the left is a dark, wooded hill in the open country, which is a mass of rhyolite-porphyry intruded in Cretaceous sandstones. It is the remnant of a tilted lens, the beds in which it is intruded being conformable in structure with those of the Crystal dome. The porphyry, which forms one or two massive outcrops on the inface of the hill, is a very white, much altered, greatly kaolinized rhyolite-porphyry of pretty fine, dense texture. This wooded hill is a conspicuous landmark for the open country on the southeast side of the mountains.

The retreat of the Cretaceous beds from the superior part of the dome to the open country has produced, as usual, the wooded coal-sandstone ridge which follows round and crosses Collar Creek. On either side of the mouth of Maiden Creek, and near Collar Creek, the coal has been prospected; but it is much crushed in the sharp upturn of the beds.

The heavy beds which form the roof of the arch are quite free from intrusions, the dike at the Florence mine and another down on the side toward Collar Gulch, with a small one in the first branch of Maiden Canyon, completing the list.

COLLAR CREEK AND GULCH.

Collar Creek rises in the mountain basin cut in the porphyry of Judith Peak and Red Mountain, and flows downward through a deep, narrow, wooded valley, all cut in porphyry, until, between the south end of Big Grassy and Collar peaks, it leaves the porphyry area and, reaching the soft beds of the Cretaceous and Jurassic strata exposed in the Crystal anticline, seeks the soft greenish shales and easily eroded beds of the Jurassic formation and cuts its way downward along them, producing a strike valley. At this point the very deeply cut valley appears almost like a deep hole between Collar, Big Grassy, and Crystal peaks. A pine-covered table of the coal sandstone ascends under Big Grassy Peak to the divide; between it and Crystal Peak is a deeply cut gulch, at the head of which is the old Collar mine and alongside of which a road descends to the bottom. In cuttings in this gulch, the soft, green Jurassic shales are found exposed—a rare occurrence, as they are generally weathered down or covered with débris in the bottoms of valleys.

From this point Collar Creek has a very steep, narrow valley, locally known as Collar Gulch; on the south there rise the huge masses of heavy limestones whose imbricated outcrops rise to Crystal Peak above. Deep, rapidly descending, dry gorges are cut in them, which contain scattered clumps of heavy timber, and in which there are several mining prospects.

On the opposite side of the gulch—the north side—rise a series of benches of Cretaceous beds in which the sandstones are well shown. Intruded in these Cretaceous beds are four heavy sheets of porphyritic phonolite (tinguaite-porphyry), the lower one from 12 to 15 feet in thickness, then two thinner ones, and another heavy one which forms the crest of the spur. These sheets split into very heavy, massive blocks, and their exposures are seen as long, low cliffs along the hill slopes. They contain a great abundance of white porphyritic feldspars, lying in a green base. In ascending to the crest of the ridge from Collar Creek, one passes over successively higher formations, as the beds are tilted in conformity with the Crystal Dome anticline, and observes the sandstones and red clays of the Dakota, while the top is formed of the black Benton shales, somewhat indurated and containing large nodules of a black, fetid limestone weathering brown gray and divided by cracks into polygonal forms, the cracks filled with gypsum or fibrous barite. The beds were searched for fossils without success.

Toward the north the upper end of this spur abuts against Collar Peak, whose porphyry mass cuts off abruptly both Cretaceous beds and phonolite sheets. An apophysis or extension of this porphyry forms a prominent knob on the slope of the spur.

The top of this spur is for some distance rather level and park-like, but a small ravine soon begins to split its outer end, between Collar Creek and West Maginnis Creek, giving rise to a drainage channel which joins Maginnis Creek a little above the fort. This drainage way at its top is sparsely clothed with pine and cedar, and affords several good exposures of the Benton shales.

Toward the southeast the spur, as it dies out in the open country, turns more to the south as the beds bend in accordance with the Crystal Peak anticline. The stream here leaves its gulch, which has been cut back into the Carboniferous, and crosses the formations successively until it emerges from its canyon into the open country, as seen to the right in Pl. LXXX. Of the phonolite sheets, only the lower one follows persistently round on the side of the dome and crosses the creek, where it is seen in the Dakota foothills. The road, following down the stream, but higher on the left bank, also crosses the beds, and the road cutting affords several good exposures.

Near the point where the stream cuts through a mass of Carboniferous limestone, forming a gateway, it seems clear from the close proximity of the Dakota formation to the Carboniferous that a considerable portion of the Jurassic beds must have been slipped back in the uprise of the dome; the exposures are not sufficient to determine which beds have slipped back, but they should undoubtedly be the soft shales. The occurrence is similar to that on the west side of Kelly Hill previously alluded to.

From what has been said, it will be seen that Collar Gulch, from the edge of the porphyry to the open country, is the exact analogue of upper Warm Spring Creek, the valley being determined as a strike one in Jurassic beds on the side of a domed anticline, and with one wall of the valley consisting of massive Carboniferous limestones, while the other is of Cretaceous beds with intruded sheets of porphyry. This is clearly shown by a comparison of sections C–C and E–E, Pls. LXXXII and LXXXIII.

MAGINNIS ANTICLINAL DOME.

About a mile south of Fort Maginnis there stands upon the open country a cluster of hills of small size but so grouped that their topography forms a significant geologic feature. An inspection of them shows that they are small monoclines, arranged in concentric lines and dipping away from a common center. In other words, they represent a domed anticline in Cretaceous beds, of precisely the same character as that on the west fork of Deer Creek previously described. The diameter of the group is about 1 mile—that is to say, the anticline shows that breadth on the surface. It is dissected by a drainage way passing through its center, and the hills cut in sandstones and red soils show that the Dakota group is mostly exposed in the uplift. It is undoubtedly due to a laccolith of porphyry not yet exposed.

JUDITH PEAK AND RED MOUNTAIN.

This is by far the largest single body of exposed igneous rock in the mountain area, measuring over 4 miles across in one direction and about 5 in its greatest length from east to west; but, as may be seen by reference to the geologic map, it is of very irregular shape. The center of it culminates in Judith Peak, the highest point in the mountains. While all the evidence goes to show that it is not a laccolith in the accepted use of that term, it is none the less an intrusive mass which has solidified under a cover of sediments, although, as the map shows, it is in contact with a variety of formations.

On the western side, between two forks of Deer Creek, the porphyry forms a high point which descends toward the north in a sharp-crested, wooded spur. This part is in contact with Cretaceous beds, and it has burst up along the southeastern side of the Deer Creek anticline without disturbing the symmetric arrangement of the beds which dip back toward it. This is well shown on the highest point of the hill, where the sandstones furnish excellent exposures. The outcrops of porphyry on the north side of the highest point are among the heaviest seen in the mountains.

On the east side of the tongue-like spur that runs north are what appear to be black Benton shales; they are largely cut down into a small gulch. East of this the porphyry recurs again and is in contact with the upturned mass of Carboniferous limestone at the heads of the east branch of Deer Creek. There can be no doubt that this mass of limestone is tilted by the porphyry and that porphyry lies under it; certainly it lies above it, separating it from the Jurassic beds. East of this the porphyry again rises into a high point and forms hill slopes facing east, where it is in contact with Jurassic beds.

At the heads of West Armell Creek the porphyry is again in contact with Carboniferous limestones, an immense block of which has been raised by the intrusion and partly filled with sheets; porphyry also underlies it, as described under the head of West Armell Creek (p. 524). Of the porphyry area which has been so far described, the slopes lead back to smooth, broad spur crests, from which, on the west side, smooth, grassy, basin-like meadows descend into the heads of Deer Creek. This is the character also of the ridge which connects Judith and Porphyry peaks, and of the ridge running to the north. These smooth, grassy basins especially characterize the areas of porphyry at the extreme head of that branch of the North Fork of Warm Spring Creek that passes Porphyry Peak. In these grassy uplands the porphyry is weathered down to a gravelly débris; no rock exposures are seen—only an occasional bowlder. Examination of the soil shows, however, that it is invariably made up of the débris of porphyry.

PORPHYRY PEAK.

Porphyry Peak, or, as it is sometimes locally called, from its dark color, "Black Mountain," is a steep, conical mass of porphyry, its sides covered with talus plates, almost without vegetation except for occasional clumps of pine. The peak is a very conspicuous object from all points of the open country below. It marks the extreme southwest extension of the great porphyry mass. It is clearly in contact here with Cretaceous beds, but what their attitude may be can not be certainly told, as there are almost no exposures. On the south base, near the stream, are sandstones which strike northeast and dip 20° NW. The branch of the North Fork which rises in the mountain meadows mentioned above, on leaving them plunges down into a steep talus-choked ravine on the southeast side of Porphyry Peak, and, emerging into a wooded bottom, joins the main stream.

The west spur of Judith Peak, in descending to the meadow basin, rises, forming a hill between two branches of the stream flowing west. This is composed of a mass of fine-grained, chocolate-colored syenite, the character of which is mentioned in the chapter on the igneous rocks (p. 561). It lies chiefly on the west side of this hill and consists of broken bowlders; no definite contact between it and the surrounding porphyry could be made out, as there are no good exposures of either to afford proof, but it is held, from its different structure, to be intruded through the porphyry as a small stock or chimney; it may, indeed, represent a former canal through which porphyry was intruded. In contrast with the surrounding porphyry the rock is hard, fresh, and unaltered. The area shown on the map is that of the broken-down rock, as seen on the surface.

JUDITH PEAK.

Judith Peak itself is composed of quartz-bearing porphyry (rhyolite-porphyry) of the type described on page 560. The small, angular, light-colored flakes compose the crest and slopes. Pine trees grow thickly upon it, and in places they have been burned and the porphyry has been reddened or blackened by the fire.

On the north side the slopes fall away into several steeply descending, half-funnel gulches. The angle of slope of the broken porphyry is extremely steep, and the gulches have almost the aspect of amphitheaters. Farther down the blocks of the broken porphyry naturally become larger.

Almost at the summit of Judith Peak, a few hundred yards northwest, the porphyry is very greatly altered, rotten, leached, and of light color. It is cut here by a vein, about 10 feet wide, of quartz and purple fluorite, upon which is located the American Flag mining claim. The same or a similar vein appears across the gulch, on the north side, and is also located.

At the summit of Judith Peak the porphyry appears crushed and filled with narrow quartz seams, which are stated to carry low values in gold. Southward from here, although the porphyry is greatly rotted and broken down, it can be seen that there is a gradual increase in the number and size of the quartz phenocrysts until, at a point perhaps a quarter of a mile east of the "Chimneys"[1], these quartzes assume a large size, the phenocrysts being often an inch or more long. The rock is now a granite-porphyry and of the character described in the chapter on the igneous rocks (p. 558). There appears in this mass, also, the same lack of definite boundaries noted in regard to the syenite, and it seems uncertain whether it is a differentiated phase or a distinct and later intrusion.

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[1] See description of the North Fork Valley, p. 515.

The quartz crystals weather out as pebbles, and very perfect specimens may be obtained.

RED MOUNTAIN.

Although one continuous mass, there is some difference between the porphyry of Judith Peak and that of Red Mountain, and this difference in character is clearly visible in the difference produced in the weathering. Instead of the hard, irregular little blocks which cover the former, the porphyry of Red Mountain is broken down into extremely small, fine débris, producing a kind of gravel in which no outcrops are seen. This gravel varies from place to place, especially in color, which grades from a strong buff to the deep red to which the mountain owes its name. The oxidation of the iron-bearing component has been so great that no specimen could be found which would show the former character of the mineral. Toward the east Red Mountain divides into two branches, one of which turns southward, while the other gives rise to a high, prominent spur, running northward and separating West Armell Creek from the eastern forks. All this part of the mountain is covered with the same hard, angular, broken down, light-colored, quartz-bearing porphyry as on Judith Peak. On the north side steep gulches covered with its débris lead down into the head of Armell Creek.

A number of dikes of phonolite-porphyry of a deep-green color, with large embedded feldspars (tinguaite-porphyry), cut the mountain in various directions. They are often broken down to a train of bowlders, but sometimes project as the heavy, massive walls seen on its eastern spurs. The porphyry is here in all directions covered with a heavy growth of small pines, which have been recently burned.

The spur that runs north from Red Mountain is itself a very large mass of igneous rock, which on the east breaks up through sharply tilted beds of the Benton formation; the slopes rise steeply and at times precipitously from the low-cut shales. In several places on the north face there are, indeed, some quite imposing amphitheaters, in which rise heads of the middle fork of Armell Creek. The rock here is fine grained but not dense, and has almost no phenocrysts; it might be termed a very fine-grained syenite. On the crest the spur, which is open and grassy, descends sharply from a high shoulder to a lower saddle, which appears to be caused by a band of sedimentary rocks—limestones—much altered and containing very thin phonolite sheets; they dip back into the hill, and on the north descend in a little ravine till they end against the upturned Cretaceous beds; they are clearly a mass of beds, probably Jurassic, which has been torn from the large blocks of sediments below and wedged off by the intrusion of porphyry. Beyond them to the west the spur rises again in a hill of porphyry, which terminates it in this direction; its north side is in contact with nearly vertical beds that appear to be of Benton age. On the south the slopes descend to West Armell Creek and are in contact with slaty beds, probably altered Jurassic, before the limestones are attained. The porphyry composing this mass is not the quartz-bearing porphyry of the higher part of the spur, but a syenite-porphyry of the Big Grassy Peak type. In this northeast portion of the great porphyry intrusion there does not appear to be very much contact metamorphism; some is noted in a hardening of the shaly beds, but this does not extend far and is not great. On the eastern side, however, where the mass ends in the saddle above Hanson's mine, at the extreme head of East Armell Creek, there appears to be a greater amount of change in the shales, which are here baked very hard.

Ascending the east spur of Red Mountain, one finds small areas—"blow-outs," as they are called by the miners—of shales, which are baked to adinoles, still sticking to the porphyry, often but a few inches thick and a yard or two across. They represent the immediate contact of the porphyry with its sedimentary cover—the thin, hard-baked skin which has not yet in places been eroded. This same character of remnants of altered shales sticking to the porphyry is found also on the broad expanses of porphyry cut into by the heads of the west fork of Maginnis Creek. Prospect pits sunk through them are found to quickly reach into the porphyry. The occurrence of these masses of altered shales on the porphyry is of interest as being considerably lower than Judith Peak and Red Mountain; it shows that the middle portion of the upper surface of this porphyry mass was higher than the edges, and had therefore something approaching a dome shape.

On the south the intrusion is cut into by the head of Collar Creek, which flows in a deep, wooded ravine with talus-covered slopes, which gradually widens at its head into open gulches descending from Judith Peak and Red Mountain. On either side the porphyry rises in narrow-crested spurs, which terminate in the high points of Big Grassy Mountain and Collar Peak. On the south side the igneous rock breaks up across the Cretaceous beds, and in the spur between Collar and West Maginnis creeks it crosses the Cretaceous section from the Dakota to the Benton, and cuts off apparently the green phonolite-porphyries which lie as intruded sheets in them. In the upper valley of the North Fork of Warm Spring Creek the porphyry descends sharply in talus-covered slopes to the low-cut shales that form the valley floor.

Throughout the whole area of this intrusion the rock is generally broken down into débris and slide-rock plates, and solid outcrops are rather uncommon, the most prominent and massive being the cliffs at the "Chimneys," in the North Fork Valley, which are really composed of granite-porphyry, and in the precipices and crags on the south side of Collar Peak, and at the head of the middle fork of Armell Creek.

A noteworthy feature of the intrusion is that wherever the periphery of the mass is examined it is found to be a syenite-porphyry of the Big Grassy type, while the main rock of the interior, as shown at the surface, is a dense quartz-bearing porphyry of the Giltedge type. There appears, therefore, a tendency for the mass to be more basic at the outer edge, and it passes, indeed, in some places into a type which distinctly recalls in structure and appearance the phonolite-porphyry of this area.

THE EASTERN PART OF THE MOUNTAINS.

EAST ARMELL CREEK.

The open country shown on the northern part of the map, between the forks of Armell Creek, is made up of grassy, rolling hills which afford few exposures of the sedimentary beds. Toward the mountains the first and most prominent outcrop that occurs is a very heavy, massive white sandstone, rather fissile, somewhat soft and crumbly, cross bedded, and forming, when tilted at medium angles to the north away from the mountains, revet hills with occasional clumps of cedars or groups of pines whose inface shows a massive, conspicuous exposure of the white sandstone. While this bed is tilted up where West Armell Creek crosses it, farther to the eastward it is nearly horizontal and furnishes, over considerable areas, a flat floor to the valley of the East Fork of Armell Creek. It stretches around the northern flanks of the foothills in a wide loop, and is again seen in a series of revet hills around the northern flanks of Black Butte, whence, as seen in the drainage cuts, it stretches eastward over the plains country. It appears to mark the top of the Benton group, and under it and toward the mountains we find the valleys cut in black shales and scored by shallow drains whose bottoms show the green lines of the oozy seepages they commonly contain.

Stretching from West Armell Creek to the head of the middle fork at the northern foot of the great porphyry mass, a distance of some 2 miles, is a series of little hills which mark the contact of the porphyry with the Cretaceous beds. They present a singular and striking geologic and topographic feature. There are about a dozen of them, in nearly a straight line, and each terminates in a knob with a double crest having a little green wooded patch on it and a light and dark streak on the side. They recall at once a row of soldiers standing in a line. They are composed of the Benton beds, which are altered and baked by the porphyry; the beds at the west end dip very steeply away from the porphyry; toward the middle of the row the dip becomes perpendicular, and toward the eastern end the dip reverses, inclining inward toward the porphyry until it becomes a part of the anticline to be mentioned later. The strike is in the direction of the row of hills, a little north of west, and a certain sandstone appears in the crest of each hill, giving the curious appearance of uniformity, which is thus, of course, due to the repetition of the same beds.

Near the middle of this line of foothills there projects northward into the valley of the middle fork a curious long gravel ridge; it is about a quarter of a mile long, not over 50 yards wide and about 20 to 30 feet high, and on top not over 15 feet wide, with a regular slope on either side; as it dies out it broadens and lowers somewhat. It is composed of pebbles of all descriptions, mostly porphyry blocks from a few inches to a foot in diameter, the smaller size predominating and the pieces being quite angular. In the lack of all other signs of glaciation in the mountains and the absence of anything in the valley that would indicate any former lake action, it is possible that the origin of this long, esker-like ridge is due to torrential action of some kind.

In the flat floor of sandstone of the open valley, between the middle fork and the main stream, a large dike occurs, forming a conspicuous wall which trends to the north. This is suspected to be of phonolite, but was not visited. The beds of the Benton group which form the floor of this valley are approximately horizontal, but are disturbed at the head of the middle fork by the intrusion of a laccolith below them, which has domed them up in an anticline whose outer limits form a circle about a mile in diameter. On the outer side the black shales of the Benton are the upper beds involved in the disturbance, and being somewhat hardened here on the south by the intrusion of the great porphyry mass, they resist erosion better than ordinarily and form a number of conspicuous coal-black exposures. Toward the center lower beds are exposed and the red clays of the Dakota group are seen, and the center itself is formed by a dome-like hill covered with sandstone. No porphyry is there exposed, but there can be no doubt that it lies below. A sheet of green porphyritic phonolite lying in the Benton is involved in the uplift, and on the map helps to bring out the structure.

In the valley of the East Fork of Armell Creek above this the porphyry of the main mass, whose walls dominate the valley, is in contact with the same Benton shales, which dip in toward it and away conformably from the Elk Peak anticline to the east. It thus appears that the great porphyry mass at every point on its periphery is erupted through the sediments without disturbing their previous structure, and it is therefore one of the last intrusions in the mountains.

The upper part of East Armell Creek, toward its head, is narrow and deeply cut, even canyon-like in places. It is here in part a strike valley. Heavy masses of syenite-porphyry have been intruded into the upturned beds, and the stream branches have deep gulches between them, some coming down from the Elk Peak dome, others from the divide and from the west. On the west side sheets of green phonolite porphyry are seen in the shales. The divide itself, which is, so to speak, threefold, in that it divides the head of East Armell Creek from both the east and the west heads of Maginnis Creek, is in the black shales; they are hardened and metamorphosed in places by the porphyry intrusions and are turned to slates. It is where these slates are cut by an altered dike that the Hanson mine is located.

WEST MAGINNIS CREEK.

Maginnis Creek, which flows down through the now abandoned fort of that name, and sinks into its stream bed in summer on reaching it, is formed by two main branches, which unite less than a mile above the fort; they are separated by a large mountain forming a spur extending southward from the main divide, called Maginnis Peak.

The west fork, or West Maginnis Creek, as it may be called, rises in a large, bowl-shaped basin surrounded by Red Mountain, Collar Peak, Maginnis Peak, and the divides connecting them. As most of the upper walls, on nearly all sides, are of porphyry, sometimes in massive exposures, but generally in broken-down talus or slide rock, the basin has but little vegetation and has a very wild and rough appearance. It is scored by shallow canyons or ravines, converging toward the center, which carry the head branches of the stream. The south side of the basin is made by the spur between this creek and Collar Gulch. The spur, as previously described, consists of Cretaceous beds, the Benton shales at the top; the strike of the beds is southeast, the dip northeast, in conformity with the Crystal Peak uplift. On this side the spur is full of intruded sheets of green phonolite-porphyry, but instead of presenting the inface or crop of the exposure, since the dip is down the slope, the broken-down backs of the sheets are presented, and instead of outcrops there are long lines of débris heaps which cover nearly all the hillside, while the sediments are not seen until the creek bottom is reached. In this the stream has cut through the sediments, showing small bluffs in which they are well exposed. They are, as at the spur top, the black Benton shales, which form all of the sediments seen in the valley; they dip slightly northeast into Maginnis Peak and form a sort of terrace or bench which rises above the stream bluff till it meets the precipitous porphyry slopes of Maginnis Peak and continues along the west base of the mountain to the Hanson divide. When they reach this divide the beds dip, however, in the opposite direction, westward, away from the Elk Peak dome, but between these points the relations are not clear, from the prevalence of porphyry débris and the lack of sufficient exposures. The stream itself presents a curious feature. There are two main forks, each of which is clear and limpid, but the moment they unite the water becomes milky from a precipitate that forms, presumably a basic iron carbonate; and this precipitate is seen for a mile below before the stream becomes clear again. Just what produces this effect can not be told without chemical investigation of the waters. It recalls the precipitates in West Armell and Edwards creeks.

The shales at the contact of the main Red Mountain porphyry mass are much altered, baked, indurated, and changed to slates, while the porphyry assumes a syenite-porphyry character with a phonolitic aspect. Sheets or dikes of phonolite are seen here; also in the shales and under Maginnis Peak their outcrops are found.

On the spur between the forks of the creek, at the contact with the hardened slates and where they are also cut by a dike, the Chicago prospect mine is located.

On its course down the valley the stream gradually cuts back into the shales toward the northeast until it reaches the igneous rock of Maginnis Peak, and the talus is found coming down to the stream.

After leaving here the stream flows through a wooded bottom with no rock exposures to its junction with the other fork in the open country. The geology of its valley is, therefore, that of the Benton beds tilted by the Crystal Peak dome, intruded with sheets of phonolite and cut off by the intrusive masses of Red Mountain and Maginnis Peak, and is seen in the geologic section E–E, Pl. LXXXIII.

MAGINNIS PEAK INTRUSIVE.

This mass of igneous rock furnishes some of the most precipitous walls and some of the heaviest exposures in the mountains, rising in cliffs and crags of naked rock where often a vertical exposure of 50 feet may be seen along the outer surface of the crags. It consists of a rock which in composition lies between a syenite and a syenite-porphyry, as described in the following chapter (p. 561). The mass appears to have broken up abruptly through the sediments and to have produced only a very local upward drag and not any far-reaching disturbance of the geologic structure of the sedimentary beds.

On the south face of the mountain, between the two forks of Maginnis Creek, there are heavy masses of the Benton shales which have been baked to tough black slates and which, resisting erosion as the unaltered ones never do, form the lower end of the spur.

On the eastern and northern sides the mountain appears to show the same features as described above, but the talus slide covers so much of the slopes that it is difficult to positively determine the structure.

EAST MAGINNIS CREEK.

This stream flows down through a deeply cut canyon-like valley with steep slopes of porphyry talus on either side. Near the mouth of this canyon the stream has cut through the Maginnis Peak syenite and its contact rim of hardened slate which forms crag-like exposures on either side. The contact is prospected by the Edwards tunnel. Above here the stream forks, and the valley widens a little and is heavily wooded. The road which is built in the valley bottom follows up the western fork and attains the Hanson divide and mine. There are several steep, narrow gulches which come into the valley from the northeast, forming other branches of the stream. They appear to be largely cut in porphyry, from the amount of slide which covers the valley slopes.

The features of the geology at the upper part of this stream are formed by sedimentary beds, mostly Cretaceous but in part Jurassic, steeply tilted on the outer side of the Elk Peak dome and intruded with porphyry sheets and masses. The gulches are, therefore, strike gulches, in part cut in the less resistant sediments, with porphyry masses forming the spurs between, and in part cut across the beds. The sediments form almost no outcrops, while the steep slopes are so marked by porphyry slide rock that one gains the impression at first, on viewing the area from one of the peaks, that there is nothing but igneous rock present. The exposures on the crests of the ridges and the material brought out from the prospect tunnels give, however, a fairly accurate idea of the geology and structure. The Maginnis Peak mass on this side, as well as the west, as described heretofore, cuts upward through the Benton beds, which form a sort of platform around it and contain one or two intruded sheets of phonolite.

From what has been said, and by reference to the geologic section E-E of Pl. LXXXIII, it may be seen that this stock of igneous rock has broken up through the syncline lying between the Crystal Peak and Elk Peak arches.

ELK PEAK ANTICLINE AND LACCOLITH.

Although this mass forms a link in the longer axis of the mountain group, it is, in a way, a geologic unit by itself. This is because it consists of a single uplift in which erosion has brought the older Paleozoic rocks to view and outlined them by the Jurassic and Cretaceous beds. Moreover, the drainages are away from it radially, so that it stands as a topographic unit. It is drained on its sides by the head of East Armell Creek, Box Elder Creek, and the heads of Ford Creek. The general geologic structure is clearly seen on the map; the beds dip away in all directions from a common center, and are very clearly raised in an anticlinal dome, due, without doubt, to heavy laccolithic intrusions of porphyry similar to those which have formed the Alpine and Burnett laccoliths. The laccolith, in the amount of denudation it exhibits, lies between them and the Flat Mountain dome; erosion has progressed further than with the latter, and the masses and sheets overlying the main porphyry mass are being brought to light. These are intruded not only in the Carboniferous, but still more so between it and the light, easily separated beds of the Jurassic and Kootanie, assuming at times the proportions of considerable laccoliths themselves.

ELK PEAK.

Elk Peak consists of a double knob, the south one being formed of massive crags of syenite-porphyry (Big Grassy type), with large glassy orthoclases. The peak commands an excellent view of the surrounding country, and the large number of stone rings made for sheltering lookouts upon it testify to the Indians' appreciation of that fact. The porphyry is the protruding edge of a thick sheet whose outcrop curves down the hill toward the east, forming a short cliff on its lower side, whose talus covers the slopes of limestone below. Another mass of quite similar porphyry occurs to the northward; it forms the crest of the ridge for some distance and finally, like the one above, descends to the northeast into Peerless Gulch, the most western of the small head forks of the Box Elder.

The crest of the ridge is made in the main, however, of Carboniferous limestone, more or less whitened by contact metamorphism, some projecting crags near the porphyry being changed to a white marble. Along this crest there are a number of prospects, the Last Chance and the Bob Ingersoll being the most developed. In addition to being cut by the porphyries mentioned it is cut also by two parallel dikes of green phonolite, one much more porphyritic than the other, about 100 yards apart and with an east-west trend; the dikes are from 5 to 10 feet wide.

On the northwest side of the dome gulches are cut back in the limestone which lead down into the head of East Armell Creek. There is a heavy mass of porphyry intruded here which furnishes some massive exposures. It rises into a hill which forms a northward-projecting spur from the dome. The saddle between the dome and the hill on the spur is formed by the Jurassic, the Cretaceous sandstones forming the hill above. Some heavy phonolite sheets are intruded in the Cretaceous, and are seen on the spurs on both sides of the drainage, while several heavy dikes of this rock are also seen cutting down through the westward-projecting spurs of the dome.

On the west the dome connects with the Hanson divide, which affords a rough section of the sequence of the beds, the higher part of the dome being of rugged slopes of bare, light-colored Carboniferous limestones, dotted with occasional clumps of pines, which lead down to the small grassy saddle that marks, as usual, the position of the Jurassic shales on a divide. Above these limestones the crest rises again, and the Jurassic limestones, with ostreas and gryphæas, are met. A sheet of phonolite crosses the ridge, and beyond are the Cretaceous beds in normal sequence.

The head of the east fork of Maginnis Creek has already been described; it is only necessary to mention a heavy mass of porphyry which has been intruded between the Jurassic beds and the Carboniferous strata, forming a spur leading to the south and between the head branches of the creek.

The porpnyry does not follow one horizon, but breaks across a number of them, like one wall of a dike. The crest of the spur shows several points of interest. After leaving the contact of the porphyry with the Carboniferous, hard, indurated shales, resembling somewhat the Cambrian shales of the region, are seen; they are the green shales of the Jurassic metamorphosed and indurated by the porphyry intrusion. Beyond are altered limestones of Jurassic character, and then sandstones with depressions marking the position of the shale beds; and eventually these sandstones, which mark the Kootanie, are succeeded by red clays baked to a brick-like consistency, which are the Dakota; succeeding them is porphyry, which ends the spur.

On the south side of the dome a spur projects between East Maginnis Creek and the next branch of Ford Creek to the east. Between the Paleozoic beds and the high part of the spur there is the usual Jurassic saddle. The spur itself, above this, is composed of Cretaceous shales and sandstones, much altered, and intruded with a very heavy mass of porphyry, which, in the crest of the spur, is about an eighth of a mile across. It is badly altered, but of the usual syenite-porphyry aspect. Above this in the sediments, or farther south, are intruded two heavy sheets of a light-colored ægirite-syenite-porphyry (Cemetery Hill type), the most southerly of which forms some heavy crags and walls that terminate the crest of the spur to the south. These sheets are from 10 to 15 feet thick. The heavy bowlders of this rock strew the hill slopes. The large amount of porphyry intruded into the upturned sediments of this spur, chiefly sandstones and black shales toward the south end, covers its western side to Maginnis Creek with such heavy masses of porphyry slide that from below it appears to be all porphyry.

From the Jurassic saddle mentioned above a gulch runs down to the east, cut in the Jurassic shales, of which, near the head, it affords some fair exposures. The shales are altered somewhat by the porphyry intrusion. The Cretaceous is in part in the gulch, and in part it forms a long spur running to the southeast, the crest corresponding with the strike of the beds, which are steeply and sharply upturned. The cause of this is the intrusion of an enormous mass of porphyry, which lies in between the massive Carboniferous and the lighter beds above. It reaches from the south spur described above; the whole upper part of the valley is cut in it, and it extends back to the divide between Elk Peak and Lewis Peak. On the east side of the valley of this fork of Ford Creek the hills are all composed of this porphyry. By inspection of the map it will be seen that the intrusion of this mass has forced back the Jurassic and Cretaceous beds until they are widely separated from the Carboniferous. Eventually the Jurassic and Cretaceous beds are broken through and turned back, the porphyry passing to higher horizons in the Cretaceous. On the southeast side of this porphyry intrusion the Jurassic beds appear in the foothills, and where they cross the spur between two little ravines good exposures of the limestones are found, with included fossils—ostreas and gryphæas. The beds are found on the sides of the hill above, with steep dip. At the most southern point, where they are pushed back, the beds are indeed vertical, or nearly so, but toward the north they eventually become much flatter in dip, as they end against the porphyry, and are exposed in two small canyons cut down through them. In some places these Jurassic beds are very greatly altered and hardened by the action of the porphyry, and this is especially noticeable where the beds end against the porphyry on the south side. They are exposed here on the crest of the ridge which separates the deeper valley of the branch of Ford Creek from the more elevated, open hill slopes which face eastward toward Ross Pass. An exposure of the shales here, where a prospect pit has been cut in them, shows them to be hard, dense, green and purple slates.

The Jurassic beds afford the usual saddle in the divide between the Elk Peak dome and Lewis Peak. On the south several long spurs of porphyry lead down into the head of the branch of Ford Creek, separating small gulches. It should be mentioned here that the porphyry composing this large mass is of a diorite-porphyry type, with few large feldspar phenocrysts, but very many small ones. In places it is extremely decomposed.

A little south of the divide the Jurassic beds, torn apart by the intrusion of the porphyry, commence again, cross through the divide as mentioned, and, trending northward with sharp easterly dip under the Lewis Peak porphyry, are cut out, as is so often the case, into a little valley. Porphyry sheets are found in them, a considerable one separating these beds from the massive Carboniferous to the west.

This little valley was visited by Dana and Grinnell, who thus mention[1] the character of the massive Carboniferous limestones exposed on its western side:

> This limestone rises in a series of sharp ridges, very distinct, and seen from a distance as a number of white lines running up the sides of the hills. It dips 50° northeast, the strike being northwest. The upper layers are white, semi-crystalline, and very profuse in flinty fragments. These are exposed by the weathering, and on the surface the rock has quite a coralline aspect. Lower layers are firmer, bluer, and also cherty, though not to the same extent as those above. A very careful search showed that fossils were very rare, though a few were found, enough to determine the age of the rock to be Carboniferous.

PEERLESS GULCH.

By reference to the map it will be noticed that the Jurassic beds form the saddle between the Carboniferous beds of the dome and the northward-projecting spur, and that as they trend eastward they are cut out into a little valley descending eastward, just as they form the northward-descending valley which is mentioned on the preceding page. Between these two gulches, whose courses are at right angles to each other, is a third, whose descending course is northeast, and at the mouth of which, before the streams come together, the Jurassic beds are cut at right angles. This is known as the Peerless Gulch, from a mine prospect situated in it, and it contains several points of interest. In the main it is cut into the sharply upturned beds of the Carboniferous limestone, which dips steeply to the northeast, in conformity with the dome structure, as mentioned by Dana and Grinnell in the paragraph just quoted.

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[1] Report of a Reconnaissance from Carroll, Montana Territory, on the Upper Missouri, to the Yellowstone National Park, and Return, made in the Summer of 1875, by William Ludlow, War Department, Washington, 1876, p. 99.

The cutting down of the gulch, however, has revealed intruded masses of porphyry, and the edge of the great sheet on the main crest above descends in a wall down the gulch, curving round as the beds are eroded. On the north side some sheets are exposed, and a very interesting feature is the intrusion of a small lens of porphyry among the upturned limestone beds; the structure is clearly seen, and the limestone is swelled in a large bubble several hundred yards across, the ordinary dip being reversed at the upper end in conformity with the intrusion. The steep cutting of the canyon wall shows the disposition of the arch admirably, and at its lower end crosses the lens so that the lower edge of the porphyry is exposed.

Porphyry intruded in the Lower Jurassic beds appears also as an exposed ridge in places, following the outer edge of the Carboniferous down into the valley below. All of these porphyries are of the usual type previously mentioned, with large orthoclase phenocrysts, and are generally considerably altered. They have metamorphosed the limestones to some extent and given rise to ore deposits, which have been prospected at a number of points.

LEWIS PEAK.

This is wholly composed of igneous rock, and on all sides except the south it presents extremely steep, talus-covered slopes. On the east they descend abruptly into Ross Pass, but on the south there is a gradual descent down the gently modeled foothill country. Geologically, Lewis Peak is a laccolith intruded in the Cretaceous beds, which is now entirely stripped of its cover by denudation. It is structurally also a part of the same mass described above as lying on the southeast side of the Elk Peak dome and forcing itself between the Carboniferous and the Jurassic beds. The igneous magma has, however, torn its way through the latter, or, in other words, they yielded to the great stretching they had undergone and the molten material passed to higher horizons, and, intruding here again on a large scale, has formed the Lewis Peak laccolith. The connection between the two masses is a quarter of a mile wide, too wide in relation to its short length to be called a dike. One can thus walk continuously on porphyry from Lewis Peak to the south side of the Elk

Peak dome. The porphyry composing Lewis Peak, however, differs somewhat from the other mass. It is of a somewhat darker color and much more dense in the groundmass. It appears, in fact, like the same magma in a much more finely crystallized condition. The hornblendes in it are also slender, acicular in form. On the west side of the peak the descent is in places quite precipitous, with columnar exposures of the porphyry. This was noted by Dana and Grinnell[1] who state that "on the western side the trachyte shows itself in a series of columns which are very regular and well formed, much more so than is common in this rock." It is, in fact, the best exposure of columnar jointing to be seen in the mountains. The geologic structure of Lewis Peak is seen in section F-F of Pl. LXXXIII.

ROSS PASS.

This forms the lowest divide in the whole mountain group along its southwest-northeast axis. It is about 5,000 feet above sea level and is less than 1,000 feet above the open-plains country on either side. The approach to it is a long, gradual ascent on either side. It is thus admirably adapted for a passage across the mountains, and is crossed by the mail route from Fort Maginnis down Box Elder Creek. The heads of Box Elder and east fork of Ford Creek rise either side of the pass, the former largely in a spring just north of the divide.

In the descriptive geology that follows under this heading are included the slopes on either side down to the plains country.

On the southwest the slopes rise with gentle modeling toward Lewis Peak, and a long ridge separates the head branches of the east fork of Ford Creek from the more western branch which drains the south side of the Elk Peak dome. Passing from the open country, which is dry, grass covered, and strewn with porphyry bowlders, and which rises gently toward the mountains, the first rock exposure is that of the heavy sandstone capping the Benton shales. This forms a series of revet hills which curve to the northwest, so that the shales form the outer southern edge of the south spur from the Elk Peak dome, and, passing westward, are in contact with the Maginnis Peak intrusion, as previously described. This heavy sandstone, although forming these noticeable hills, as soon as it strikes the alluvial flat formed by the branch of Ford Creek draining the south side of the Elk Peak dome as it issues into the open country, disappears and is not again noticeable on this side of the mountains. Toward the east it curves somewhat to the north, forming more revet hills, which are the southern foothills of the mountain mass on the east side of Ross Pass. These are cut through by the drainage channels from the south side of the mountains, and at the point where the east fork of Ford Creek cuts through there is a quite deep valley with prominent bluffs on either side, with the heavy sandstone capping showing very prominently as it starts at the high upstream end of the hill and dips slowly downstream until it reaches the stream level. This bluff, especially on the east side near the Bessey ranch, furnishes the best section of the Benton group seen in the mountains, and it was here that the section of these beds given in Chapter III (p. 482) was made.

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[1] Op. cit., p. 98.

It will be noticed on the map that the stream forks, the eastern fork coming down from a valley cut in the porphyry mass on the east of the pass, while the western branch drains the southern slopes of Lewis Peak. Both branches cut shallow drains in the Cretaceous beds; and the hill slopes, as soon as the Benton shales are left, exhibit the red soils of the Dakota group. On the east side of the east fork the indurated sandstone at the top of the Dakota forms a long, conspicuous, tree-covered ledge along the valley side, the top of which is a terrace covered with the bowlders and débris of a broken-down sheet of phonolite-porphyry (tinguaite). The western hill slopes are also strewn with the thin, brown, indurated plates of this sandstone, above which are the red clays already mentioned. Until one reaches the upturned beds of the Jurassic formation which lie on the back of the laccolith, as previously mentioned, there are no exposures which are sufficiently clear to determine whether the Kootanie beds occur here also, but from the position of the other sediments it is believed that they undoubtedly must. An interesting feature is a very small domed anticline in these southern foothills, which exposes black shales in its center. It is shown by a structure-line on the map, and is thought to bring the Kootanie beds up in the exposure.

As one approaches the pass the red clays and sandstones of the Dakota group become more and more in evidence, and at the lowest point in the divide they form the surface exposures. They are also seen down on the Box Elder side of the pass. The beds at the east and north foot of Lewis Peak are very sharply upturned, producing a series of small revet hills. Below, on Box Elder Creek, the slopes are smooth and grassy, without rock exposures.

CONE BUTTE MOUNTAINS.

On the east side of Ross Pass rises a mountain mass of porphyry, its most northern point forming a very sharp and quite symmetric conical hill, which, being a prominent landmark, has long been known under the name of Cone Butte. Of Cone Butte itself a more detailed mention will be given later. It is introduced at this point only to call attention to the fact that in the lack of any name for this general mountain mass it will be spoken of here as the Cone Butte Mountains, since, being quite deeply dissected by erosion, it gives from a distance the impression of a cluster of peaks rather than that of the single unit mass it really is.

On its western side this mass of igneous rock rests on Cretaceous beds—the top of the Dakota, as previously mentioned—which here dip in under the porphyry at an angle of about 10°; that is, they dip east. They form a terrace, and from them the porphyry slope springs abruptly up at a steep angle. Hence, along the western front of the mass the beds are not turned up by the porphyry, but, on the contrary, it rests upon them, and the base of the laccolith is thus exposed. The porphyry composing the mass is more or less altered, and of the character of that forming Lewis Peak, as described on page 565. It is generally more or less decomposed and in places forms a reddish gravel. This is especially noticeable on the eastern side of the mass. And a knob of this porphyry between the extreme heads of Edwards and Little Box Elder creeks resembles in all essential respects—in its weathering, alteration, and colors—the porphyry débris of Red Mountain, described on page 536.

In all directions erosion has scored deep V-shaped valleys or ravines in this mass, from which the drainage is radially outward. The north sides of these valley slopes are covered with thick forests of small pine trees, while the south sides to the spur crests are open and grassy, often with broken-down rock barely concealed by the grass—a difficult and tiresome slope to ride or walk over. The spurs and hills are somewhat variable in their profile, but culminate in the highest point of the mass—the triangulation peak shown on the map just south of Cone Butte.

In all directions the porphyry is cut by dikes of greenish phonolite, with embedded white feldspar phenocrysts (tinguaite-porphyry), a detailed description of which is given in the next chapter (p. 567), the dike between Cone Butte and the peak south being selected as a type, as all the others closely resemble it. In width these dikes vary from 5 to 15 feet; in many places they form heavy, massive, conspicuous walls, cutting the smooth slopes; in others they are broken down into rock heaps and trains of bowlders whose linear extension alone gives hint of the dike structure. On the northeast slopes, in fact, these dikes are so thick and so much broken down and the débris so scattered that it is difficult to tell which mass really represents the site of the dike and which is transported material.

On the eastern and northeastern sides the porphyry is in contact with the Benton beds, and this appears to be true also on the southwest and extreme south, as previously noted in Ross Pass; but on the southeast this is not the case, and the spurs here show the porphyry in contact with thin-bedded, much-altered limestones which, although no fossils have been found in them, are believed to be of Jurassic age, both from their lithologic character and appearance and from the fact that the beds of this age have so generally suffered intrusions in this mountain area. Moreover, they are certainly not the massive Carboniferous, and this horizon is nowhere exposed in this part of the region. These limestones, with associated shales changed to slates, and sandstones altered to quartzite, are seen on a number of spurs on the southeast side, where they come in contact with the porphyry, and are also cut by dikes around the head of Edwards Creek.

The amount of contact metamorphism the Cretaceous rocks have suffered through the intrusion of this igneous mass, though extending but a short distance from the contact, is considerable for a few rods. The shales and limy beds are changed to hard, tough, gray, green, and black slates, which have all the appearance and character of similar rocks found only in the Archean in Montana. In two areas shown on the map, patches of these altered sediments are found, still uneroded, on the back of the laccolith. These are baked and altered in the same way and show the same metamorphic character. They contain considerable altered limestone, and the most northern is, in fact, a limestone changed to a hard, white crystalline marble. There is but a small patch of it ("blow-out" of the prospectors), completely surrounded by porphyry, and but a few feet in thickness, as shown by the prospect pits penetrating it. From its evident limestone character it is assigned to the Jurassic, as is also, for similar reasons, the rock of the southern area.

On the extreme east, in the saddle between this laccolith and that of Lookout Peak, the porphyry is in contact with a sandstone underlying Benton shales. This sandstone is changed, by contact metamorphism, to an extremely dense, tough, hard, blue quartzite, resembling those of Archean areas. Considerable talus slides of it are seen on the slopes leading down into the head of Edwards Creek.

In the ravine which separates Cone Butte from the peak to the south a series of altered slates also occurs, as mentioned by Dana and Grinnell,[1] who say:

> In the ravine spoken of, 355 feet below the summit of Cone Butte, we were surprised to find a series of slates and sandstones. * * * The total width of the gap is about 70 yards, the trachyte [porphyry] rising abruptly on both sides. The section [of the beds] in the gap is as follows:
>
> | | Feet. |
> |---|---|
> | Coarse ferruginous sandstone, vertical | 8 |
> | Fine blue shale, vertical | 20 |
> | Slate, sometimes shaly, sometimes a good slate, and very sandy, in layers; color whitish and yellowish; dip, 70° south | 180 to 200 |
>
> The strike of these slates is east and west. The age of these rocks is uncertain, as the only fossils found in them were some cycloidal fish-scales, with occasional impressions of fish-vertebræ and spines, which were quite numerous in some layers in the slate. It is hardly to be doubted, however, that they are Cretaceous. * * * The present position of these slates is very remarkable; they lie far above (about 600 feet) the rocks visible in the hills below, and doubtless owe their elevation to the eruption of the trachyte, having been squeezed up between the two great masses of igneous rock.

By reference to the Cretaceous section given on page 482, it will be seen that these beds are of the upper part of the Benton group.

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[1] Report of a Reconnaissance, etc. (see footnote on p. 545), pp. 98-99.

Their occurrence is, as mentioned above, a matter of interest in that they afford another instance of how warped and irregular the upper surface of the laccolithic intrusion was.

CONE BUTTE.

This is described by Dana and Grinnell[1] as follows:

> The summit of Cone Butte commands an extensive view over the prairies of the north. The Little Rocky and the Bear's Paw Mountains, though far in the distance, are the most conspicuous points to be noticed. * * *
>
> Cone Butte is itself a conspicuous object from all the surrounding country, even as far north as the Little Rocky Mountains, its perfectly conical shape being very striking from any point on the Carroll[2] road. Viewed from the west the sides of the cone are broken, and not so symmetrical as shown in [the] figure. The slopes are covered with loose blocks of trachyte [porphyry] and at some points are precipitous. The angle of the cone is about 40° or 41°; indeed, it is so steep, and the loose blocks of trachyte furnish so insecure a foothold that, were it not for the trails made by the mountain-sheep ascending and descending, it would be no easy task to climb it from the west side.

In addition to this it is only necessary to note that the precipitous portions on the east side of the butte furnish good examples of columnar structure in the porphyry, the jointing being perpendicular and forming huge slabs standing on end. On the north side the talus descends to grassy slopes, where the heavy white sandstone forming the top of the Benton group is exposed.

INTRUDED SHEETS AND DIKES ON SOUTH SIDE.

On the south side of the mountain mass there are a number of small, narrow, deep ravines which cut down from the porphyry basins above, through the hardened zone of contact rocks with intruded sheets upturned against the porphyry, to the wide open Cretaceous drains below. They usually contain small rills of water rising in springs above, and furnish head branches to the east fork of Ford Creek. There are several occurrences of igneous rocks here which are of sufficient interest and importance to justify a more detailed description.

At the south end of the porphyry mass is the point shown on the map as the triangulation point. From this a heavy dike runs southward, forming a conspicuous wall 15 feet broad along the slope. This dike descends to the sedimentary beds below, and there abruptly ends as a dike, but continues eastward as an intruded sheet 10 to 20 feet thick. Another large dike also descends the hill, with southwest trend, to the intersection of dike and sheet above. The rock composing these is much altered, but is a feldspar-porphyry.

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[1] Op. cit., pp. 96-97.

[2] A former important steamboat landing on the Missouri River near the head of summer navigation. A freight road led thence to Helena and other points in western Montana, passing the Judith Mountains.

Beyond these to the east are several intruded sheets of green phonolite-porphyry (tinguaite), one of which is extremely dense and without any phenocrysts. They are intruded in the black Benton shales, which are somewhat indurated by metamorphic action, so that exposures of them are seen in the small gulches.

Still farther eastward, on the southeast side of the great laccolith, there are several dikes of green phonolite which run out from the porphyry, forming the crests of spurs and cutting the altered sediments. They expand into the strata in the form of intruded sheets as they extend outward, and eventually give rise to a sheet at least 50 feet in thickness, which terminates them. This sheet thus appears fed at several points, and the ravines between the dike spurs form short, narrow canyons through it and the upturned metamorphosed sediments above and below it, which afford excellent exposures. The sheet is really a small laccolith or lens standing tilted up at a considerable angle; it thins out rapidly both east and west. The rock is a light-colored feldspathic one, described in the succeeding chapter (p. 566); at the contact it has the green phonolite (tinguaite) facies, and it is believed to be the same magma as that composing the dikes and sheets in a more coarsely crystallized form, but chemical analysis would be required to definitely decide the point. The contact edges of the main porphyry have also a distinct phonolitic facies all through this part of the area. The whole occurrence is of great interest, as it gives a distinct clew to the origin of the abundant phonolite dikes cutting the main porphyry mass and the intruded sheets of the same rock in the sediments surrounding; this feature is fully described in the next chapter (pp. 572-574).

A feature of interest occurs in the upper part of Edwards Creek. In the ravine it forms in the mountains, before it debouches on the plain, there are quite thick deposits of limonite along the banks, perfectly similar to that described as occurring between the head forks of East Armell Creek. This deposit is of interest when it is noticed that the water in the stream drains, in part, from the gravelly, reddened, leached porphyry hill of the east side of the Cone Butte Mountain mass, as previously mentioned above, just as East Armell Creek and West Maginnis Creek drain from the similar porphyry of Red Mountain, and both contain iron deposits. The cause of this action is by no means clear, but there is certainly some connection between this altered porphyry and the iron hydroxide in the streams below.

LOOKOUT PEAK LACCOLITH.

The mountain area of the Cone Butte Mountains is prolonged to the eastward by another intruded laccolithic mass of porphyry, to which the name of Lookout Peak has been given on account of the magnificent view in eastward directions which it affords, there being, with the exception of Black Butte, no other elevation to interrupt the outlook to the horizon's rim.

Between this mass and the one to the west is a deep saddle cut in black shales of the Benton group. It is traversed by two dikes of phonolite, and a spring rises in it. The exposures of the soft shales are not such as to give any definite clew concerning the dip and strike of the strata, but from analogy and from what is known elsewhere it is believed that the beds run in under the porphyry at a moderate angle of dip. The porphyry itself is similar to that of the larger mass. It is cut by phonolite dikes, surrounded by fringing sheets of the same, and is in all respects similar to the larger mass to the west, which it accompanies like a satellite, and of which it is a miniature. At the extreme east end there is a little patch of baked and altered sediments, apparently on the porphyry, and beyond this is a mass of the light-colored feldspar-porphyry similar to that described in the previous section. It appears to be a dike, but the exposure is not altogether conclusive, and it may be a border facies of the main mass.

The steep slopes of porphyry talus descend to the revet hills of Cretaceous below, which are upturned sharply on all sides and contain several intruded sheets of phonolite.

BLACK BUTTE.

This mountain rises as an isolated mass at the east end of the group, towering above the open, gently contoured plains country that surrounds it on all sides. An interval of about 2 miles of this country separates its western foot-slopes from those of the nearest point in the mountains, Lookout Peak.

The butte has at first rather smooth, gently ascending slopes, grassy, and cut by small drainage valleys. Toward the butte these grow steeper, and at an altitude of about 600 feet above the plain talus slopes are met, and from here all is rock to the top. The sides are very steep, and are composed mainly of broken slide rock, with occasional crags and small precipices, and scored by narrow ravines, which at the south end become a number of deeply cut gulches, with heavy buttresses of naked rock on either side.

The slopes are dotted with occasional pines and bushes, but timber of good size is found only in several of the deeper ravines. At the head of the grassy slopes, below the line of talus, several springs break out around the sides of the butte. The crest is about 1,500 feet above the open country below.

This mountain is composed in part of a mass of granite-porphyry, upthrust through the heavier strata of the Paleozoic beds below into the lighter strata of the Cretaceous beds above. This mass has upturned with it a great block of these Paleozoic strata, which is tilted against its southern flank, and now, denuded of its sedimentary cover, the butte consists of a mass of granite-porphyry in its northern half, while the southern portion consists of the upturned Paleozoic beds, which dip at very steep angles to the southward and lie against the porphyry. This is shown in fig. 48, which presents a map of the butte, and the cross section, fig. 49, gives an idea of the geologic relations and shows that it is an asymmetric laccolith.

The porphyry composing this mass is described in the following chapter (p. 559). At the contact with the sediments it changes to a felsite, very dense and compact, of a deep-red color.

Immediately in contact with the porphyry, on the south side, is a heavy, massive quartzite, about 100 feet in thickness, which is succeeded by Cambrian slates of the usual lenticular variety. They are very greatly indurated and metamorphosed, and a couple of sheets of porphyry are intruded in them. This quartzite is of interest, as it represents the lowest horizon of this age which has been seen in the area; it occurs nowhere else.

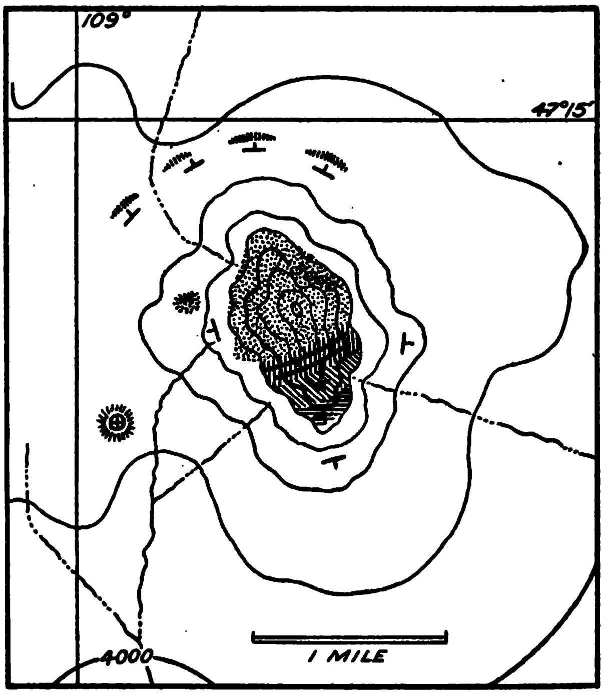

FIG. 48.—Geologic map of Black Butte. White area, Cretaceous, the sandstone reef encircling the butte shown by hachures. The stippled area is granite-porphyry. The vertical lines show Cambrian limestones with two intruded sheets of porphyry.

Succeeding the Cambrian beds are strata of massive limestones, which are greatly changed by metamorphism, being whitened to marble and filled with seams and cavities full of crystallized quartz and calcite, while others are of rich purple color, due to the presence of fluorite.

The limestones in turn give place to thinner beds of shales and limy shales, which have been changed to hard, dense, tough, green, gray, and purple slates and schists. They would be difficult to tell from the altered Cambrian were it not for the lenticular structure of the latter, while both these have all the characters of hard, schistose rocks belonging to the Archean formation. These altered beds give place in the south slopes to strata which eventually are of normal Cretaceous aspect.

The amount of contact metamorphism in this upturned block is very great, and surprisingly so when the much less altered character of the sediments around the northern part of the base is taken into account. These latter appear to be the Benton shales, which apparently formed the cover of the laccolith. The sandstone capping them forms a series of revet hills around the north end, in which the white upturned sandstone is very conspicuous. These hills are indicated on the sketch map. This sandstone recurs again in a little hill southwest of the butte, where it is horizontal. Somewhat nearer to the butte on the west is a little hill in which porphyry is exposed.

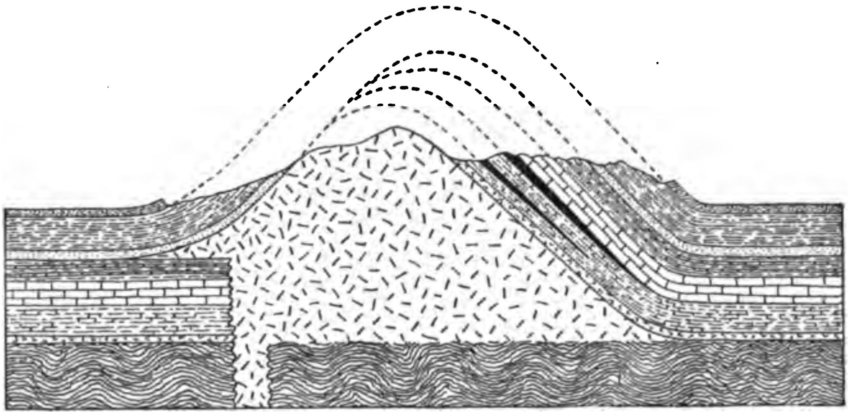

FIG. 49.—Cross section north and south through Black Butte, showing asymmetric laccolith.

The section, fig. 49, shows in a general way the manner in which the beds have been upturned, but this has not been an absolutely regular process, because in the breaking loose and thrusting back the stratigraphic relations have been disturbed in places; faults occur, and in one place the Cambrian overrides the Carboniferous, while in another place a block of brown sandstone appears under a part of the Carboniferous in nearly horizontal position, as if thrust in under it.

It is believed that the sedimentary strata are in the main, however, represented in their normal sequence, as the beds show the regular characters typical for the district, the contact metamorphism being taken into account. It is not thought that the whole thickness of the Cambrian is represented, nor that of the whole limestone section from the Silurian to the top of the Carboniferous, and probably a portion of the Jurassic is also wanting. It spite of the excellent exposures, it is not possible, owing to the faulting and metamorphism, to make a satisfactory section, but it is believed that in the upturning of the beds some of the strata have been crowded or pinched back, as has happened elsewhere in the district under such circumstances.

The zone of altered limestone has been prospected for ores, but so far nothing has been found which would warrant development. The isolated position of the mountain and scarcity of an available water and timber supply render it an unfavorable locality for mining any but ores rich enough to stand the cost of transportation.

COUNTRY SOUTH OF THE CONE BUTTE MOUNTAINS.

This is of the general character of the open country elsewhere described in this report. Bordering the streams are long and often wide stretches of alluvial flats, while the shallow open valleys are bordered by planation tables and terraces. The beds are those of the upper Cretaceous section, and exposures of them are rarely to be found, the gently contoured country being mantled everywhere by soil with a growth of grass upon it. A certain amount of moisture seeps along the drainage ways, as shown by the brighter color of the vegetation, and these, with the valleys of the running streams, are taken up by the ranchmen, while the intervening stony flats and terraces, often thickly covered with fragments of the mountain porphyries and green phonolite, are used only for the pasturage of their herds.

CHAPTER V.

By L. V. Pirsson.

THE IGNEOUS ROCKS.

INTRODUCTION.

In some respects the igneous rocks of the Judith Mountains have already been described, where, under the descriptive geology, the general appearance of each type has been mentioned in connection with its occurrence. The aim of the present chapter is not, therefore, to present a detailed account of the various occurrences, but to give a generalized account or summary of the facts observed in the field, together with enough petrographic detail to enable one to recognize the various types occurring in the area described and to understand their petrologic significance and bearing. The field occurrences have been given in detail and will not be repeated here, while the general relation of the igneous masses to the broader problems of structural geology will be found set forth in the succeeding chapter. Thus the aim of the present chapter is chiefly petrologic, yet it is not intended at the present time to give a complete study of all of the rocks of the district, but to present data concerning the more important types sufficient to achieve the purpose mentioned above. The complete study it is hoped will be published elsewhere at a future date.

The igneous rocks of the Judith Mountains belong to only a few types, are of simple mineral composition, and are all acid rocks; that is, the amount of silica in them varies from 57 to 75 per cent. One or two types approach what may be called a medium composition, but it is a remarkable fact that in a district of such considerable size and with so many occurrences of igneous rocks there is not a single occurrence of what may be called a basic rock; they are all of light-colored feldspathic aspect, dark-colored pyroxenic rocks being absolutely wanting.

Alkaline types, rocks deficient in lime, iron, and magnesia, with high alumina and alkalies, are common in the district, and the element that varies chiefly is silica; accordingly, members of the granite, syenite, diorite, and nephelite-syenite families are found, the latter being represented by rocks of phonolitic character.

GRANITE FAMILY.

The granite family, consisting of rocks composed of alkali feldspar and quartz, with some other accessory minerals which may or may not be present, is very largely represented, but true granite, consisting of these minerals in a granular, nonporphyritic structure, does not occur. There are, indeed, in the district, one or two occurrences of granular rocks which are not porphyries, but as these are composed chiefly of alkali feldspar, they should be termed syenites, lacking, as they do, the quartz necessary for the granite. Among mining men in the West the term granite is so generally applied to all granular rocks without regard to their mineral composition that these would also undoubtedly be termed granites, but according to more strict petrologic usage they would be termed syenites. The granite family, then, is not represented by its granular member, but by the finer-grained porphyritic types, such as granite-porphyry and the still finer-grained and less porphyritic rhyolite-porphyries (commonly called quartz-porphyries).

GRANITE-PORPHYRY.

This rock constitutes a portion of the Judith Peak massif, forming there apparently a chimney or small stock intruded in the quartz-bearing porphyry, as described in the account of the Judith Peak mass on page 535. As no distinct contacts were found, it is not certain whether it is a differentiated portion of the whole mass or a separate, later intrusion.

Megascopic appearance.—In the hand specimen the rock has a light brownish-green color; it has a pale greenish-gray matrix, of a very dense, hornlike appearance, in which are embedded great quantities of a pale-gray feldspar, appearing as small square phenocrysts 1 or 2^{mm} in diameter; these are present in equal amount with the matrix. The other porphyritic component is quartz, which appears in large phenocrysts, at times one-half inch or more in diameter. The cross sections of these large quartzes show them to have (megascopically) a zonal structure. This seems remarkable with quartz, but is nevertheless clearly visible, and it would appear as if the mineral had had a renewed period of growth in which the new material differed somewhat in its physical characters from the older interior part; examined with a strong lens the difference disappears. These quartzes weather out on the rock, and many of them are extremely perfect dihexahedrons with a short prism. Crystals over 10^{mm} in length are not uncommon, and as the edges, angles, and symmetry are very perfect they make attractive mineral specimens; only the luster of the faces is wanting to distinguish them from ordinary crystals of solution, though they are not limpid, as many of the latter are. They are, in fact, with respect to their size and perfection, the most remarkable quartz phenocrysts that have come under the eye of the writer. Such may have been mentioned in the literature, but no description of them has been seen.

No ferromagnesian mineral is megascopically visible.

Microscopic characters.—In thin section the quartz shows nothing remarkable beyond its size and the fact that certain grains penetrate, so to speak, on their outer boundary, into the groundmass and include quantities of small crystals of the minerals composing it. Sometimes they are cracked, and the cracks are filled with a pale-yellow substance which shows a spherulitic structure between crossed nicols, like many of the flow-lines of chain spherulites seen in rhyolites.

The feldspar phenocrysts which have been mentioned are composed in the main of an unstriated feldspar, which is probably orthoclase, containing quantities of small crystals, and rather large microlites of albite much twinned. These latter are often arranged in a rudely zonal structure, and the whole appearance of the phenocrysts is precisely similar to that of the feldspar phenocrysts described by the authors in the syenite-porphyry of Lookout Butte in the Little Rocky Mountains[1] and in that of Gray Butte in the Bearpaw Mountains;[2] while somewhat related occurrences have been described by Brögger.[3]

The groundmass between these feldspars, which is small in amount, is made up of microlites of albite, small irregular patches of anorthoclase, and occasional small areas of a spherulitic character, which appear like little patches of devitrified glass, together with small prisms of ægirite. These are mingled in a microgranitic structure. The ægirite has the usual optical characters, pyroxene cleavage, and crystal form, but is of a rather light tone, more the character of an ægirite-augite; nevertheless the bisectrix $\mathfrak{a}$ lies close to the crystallographic axis.

This occurrence of an ægirite-granite-porphyry is of great interest, as such rocks are extremely rare, and the present instance is quite typical.

At the "Chimneys," in the valley of the North Fork, which form the boundary of this granite-porphyry in one direction, the rock has a gneissoid look, owing to the fact that the huge quartz phenocrysts have been cracked up into a series of chips and distributed along in streaks showing the flowage action of the ascending magma as well as the intratelluric origin of the quartzes.

Granite-porphyry also occurs at Black Butte, of which it forms the chief mass. This variety is more like that of the ordinary type of such rocks, with rather small quartzes, which are not very abundant, and numerous black hornblende prisms.

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[1] Geology of the Little Rocky Mountains, Weed and Pirsson: Jour. Geol., Vol. IV, 1896, p. 422.

[2] Bearpaw Mountains, Montana, Weed and Pirsson: Am. Jour. Sci., 4th series. Vol. I, 1896, p. 291.

[3] Grorudit-Tinguait Serie, Christiania, 1894, p. 17.

RHYOLITE-PORPHYRY ("QUARTZ-PORPHYRY").

This is probably the most common rock in the Judith Mountains, forming everywhere numbers of intruded sheets, as well as masses of the laccoliths. It rarely occurs in a fresh condition, and a typical specimen from the intrusive porphyry sheet on the spur above the Giltedge mine is selected for description.

Megascopic characters.—The rock does not occur in large blocks, but is cracked into small angular fragments a few inches square. These fragments on a weathered surface are of a light brownish-buff color, often turning to a darker brown or crimson on the edges, sometimes a straw-yellow. When broken with a hammer the pieces often show that they have broken along a joint face and are dark and discolored from infiltrated iron oxides; when the break is across fresh material the rock has a pale-brown color.

The outer exposed faces of these fragments show only matrix and no phenocrysts, the place which they formerly occupied being represented by quantities of small angular pits dotting the surface of the rock and giving it a cavernous appearance.

The broken surface of fresh portions shows a dense, flinty matrix of a light-brown color, in which are embedded considerable numbers of small feldspar and quartz phenocrysts, which speckle it with lighter-colored spots; these embedded crystals are from 1^{mm} to 2^{mm} across. Small rusty spots show the presence of some former iron-bearing mineral, which is now decayed.

Microscopic characters.—Under the microscope the thin section of this rock shows a very fine groundmass made up of a mixture of quartz and alkali-feldspar granules in allotriomorphic structure. Embedded in this are occasional quartzes of the rounded, corroded type common in such rocks; they are not abundant. In addition there are occasional sections, mostly converted to clay and sericite, which are the former feldspar phenocrysts; while an occasional one of muscovite stained with iron ore indicates that biotite was probably present. The groundmass is filled with fine shreds of sericite, and the rock is everywhere stained with secondary iron; everything, in fact, shows that it has been much altered.

The rock shows all the typical characters of the intrusive rhyolite-porphyries (generally called quartz-porphyries) which occur so widely in Europe—in the "elvans" and acid "sills" of England and the "quartz-porphyry" masses in Germany and elsewhere.

The rocks of which the above may be taken as a type, as noted in the descriptive chapters, occur in a great number of localities, the laccolithic masses of the southwest part of the mountains, with the numbers of intrusive sheets above them, being the main occurrences. The intruded sheets above the town of Maiden, a considerable portion of the Gold Hill intrusion, and large areas of the Judith Peak mass may also be added.

SYENITE FAMILY.

Rocks of the syenite family, consisting chiefly of alkali feldspars, are not uncommon in this region. They include syenite and syenite-porphyries, and a number of important occurrences of what may be called syeno-diorite-porphyries, rocks transitional to the diorite family, with some types actually belonging to the latter.

SYENITE.

What appears to be a small intrusive stock of this rock occurs on Judith Peak, about a mile west of the peak proper, at the head of the north branch of the North Fork Creek. It does not have exposures which enable one to infer definitely concerning its relation to the surrounding porphyry. It has been described in Chapter IV under the account of the Judith Peak intrusion (p. 535).

Megascopic characters.—On a fresh fracture the rock appears of a dark brownish gray with a reddish tone; it appears clearly granular without porphyritic crystals; the grain is rather fine, the rock feldspathic with dark-colored ferromagnesian minerals very sparingly present. This lack of colored minerals and its compact fine grain make the rock appear very similar to many granitic aplites.

Microscopic characters.—In thin section the rock appears composed chiefly of unstriated alkali feldspar, with a good deal of striated feldspar, an oligoclase, present in somewhat larger crystals. These feldspars are rather idiomorphic but thickly crowded, and the small interspaces are filled with finer grains of the same, mingled with some of quartz; the amount of this latter mineral is small and by no means sufficient to throw the rock into the granite group.

In addition to these minerals there is a small amount of pyroxene present in the shape of occasional prisms of a clear, sea-green diopside, and this, with a little iron ore, titanite, and apatite, completes the list. The structure is granitic, the rock very fresh and unaltered.

A syenite which closely resembles this occurs at Yogo Peak, in the Little Belt Range, Montana, and has been described by the authors,[1] but the present type does not probably contain as much lime, iron, and magnesia. The amount of plagioclase present is, however, considerable, and the rock inclines toward the diorites or toward the family which Brögger[2] has classified as the monzonites; in this classification it would lie between a typical alkali syenite and a banatite.

A rock of very similar character to this syenite of Judith Peak constitutes the mass of Maginnis Peak. It is, however, distinctly finer grained, and there is a decided approach to a porphyritic development of the feldspars, which in places carries the rock into a distinct porphyry. It thus stands on the border line between a syenite and a syenite-porphyry. The same is true of that portion of the Judith Peak-Red Mountain intrusive mass which lies at the head of the middle fork of Armell Creek, the high spur which sets out to the north from Red Mountain.

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[1] Igneous rocks of Yogo Peak, by Weed and Pirsson: Am. Jour. Sci., 3d series, Vol. L, 1895, p. 470.

[2] Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol, 1895, p. 21.

The rock here is almost without phenocrysts, but the grain is very fine. Separated by intervals of several inches are found sporadic feldspar phenocrysts. The rock might be described, perhaps, as syenite-porphyry with the phenocrysts wanting. The groundmass is distinctly granular to the eye and as fine as many aplitic rocks. These types are transitional to the syenite-porphyries.

SYENITE-PORPHYRIES AND DIORITE-PORPHYRIES.

GENERAL DISCUSSION.

As previously remarked, rocks of this class are very common in the district, but under this name is included not only typical syenite-porphyries but also a number of rocks in which there is a considerable amount of free quartz. This quartz does not appear, however, in the shape of phenocrysts, and is not, therefore, megascopically visible; it is entirely concealed in the groundmass, and many of the rocks, both on account of the lesser amount of quartz and the habit they possess, stand as a transition type between the granite-porphyries or rhyolite-porphyries on the one hand and the true syenite-porphyries on the other. It seems best, therefore, to call these rocks quartz-bearing syenite-porphyries. They might, indeed, be termed felsite-porphyry, but the name is rather objectionable, and with their abundance of large alkali-feldspar phenocrysts and granular-looking groundmasses they do not at all resemble those rocks which have been called felsites.

In another way these rocks are difficult of classification, in that they grade from types which are clearly syenite-porphyries, in which alkali feldspars predominate, into types in which just as clearly plagioclase or soda-lime feldspars predominate, and hence are diorite-porphyries. Probably the most common rock of them all is one which contains numbers of very large idiomorphic phenocrysts of orthoclase, often an inch or more long, and much more numerous phenocrysts of plagioclase, varying from oligoclase to andesine, whose size is about that of coarse shot, embedded in a groundmass of alkali feldspar and quartz. The light-colored surfaces of this rock are dotted by small prisms of a black, glittering hornblende. The rock of Maiden Peak illustrates this type. It is a very common type of rock in western America, and it is probably the most common one found in laccolithic intrusions—so common, indeed, that some authors have been inclined to see a special connection between the type and that mode of geologic occurrence.

Cross[1] has described a number of occurrences of this intermediate type from the laccolithic mountain groups of the central plateau region under the name of diorite-porphyrites and hornblende-porphyrites. Lindgren[2] also mentions rocks of this character from the Moccasin Mountains and other localities in Montana, and calls them porphyrites. In a previous paper[3] they were called dacites. These Montana localities, so briefly described by Lindgren as the result of his reconnaissance work, have been more fully studied by us, and in the course of our work we have found numbers of these rocks, occurring in various modes of intrusion.

Other examples might be cited, but the above are sufficient to show that the type is a common and well-recognized one, and that the rocks have been generally called porphyrites or diorite-porphyrites, and thus placed in the diorite family.

In some cases the classification adopted for these rocks has been based wholly on the dominant phenocryst, and no account has been taken of the groundmass. While often the plagioclase phenocrysts are numerically the greater, if the whole amount of alkali feldspar present in the rock, in opposition to the plagioclase present, should be summed up, the former in many cases would exceed; and it can not be correct to call such a rock a member of the diorite family, in which a lime-soda feldspar is supposed to dominate. Carried out with logical correctness, the transition would present the following types:

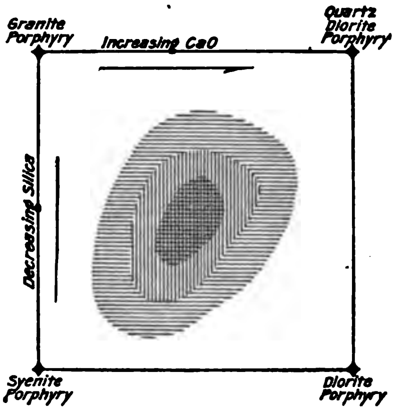

FIG. 50. — Graphic representation of rock-type relationships.

Granite-porphyry Grano-diorite-porphyry Dioro-granite-porphyry Quartz-diorite-porphyry
Syenite-porphyry Dioro-syenite-porphyry Syeno-diorite-porphyry Diorite-porphyry

These relations are best seen in fig. 50, in which the more heavily shaded parts indicate the more common type.

Analyses of this class of rocks frequently show that, magnesia and iron being low, the lime is compelled to enter the feldspar, and thus a comparatively small amount of lime will turn a large amount of soda into an acid oligoclase, which might otherwise have formed alkali feldspar with the potash. With more magnesia and iron present the lime might enter wholly into hornblende or pyroxene, and, the feldspar being a nonstriated one, the rock would be classed as belonging to the syenite family.

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[1] Laccolitic mountain groups, etc.: Fourteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 157.
[2] A sodalite syenite, etc.: Am. Jour. Sci., 3d series, 1893, Vol. XLV, p. 286.
[3] Eruptive rocks from Montana: Proc. California Acad. Nat. Sci., Ser. II, Vol. III, p. 39.

The writer's feeling in regard to the matter is that such rocks may, for ordinary field purposes, be termed simply "porphyries," or if the character of the prevailing phenocrysts can be made out on a cleavage surface by the lens (which will rarely happen), it may then be termed diorite- or syenite-porphyry; but when the rock is subjected to petrographic study, it should not be classified by the phenocrysts alone, but by the total feldspar present, and, if necessary, chemical determinations should control the microscopic analysis.

Brögger[1] has attempted to meet the difficulty of the proper classification of transition types between the alkali and the soda-lime feldspar rocks, in the case of the granular rocks, by proposing a new class for them, the monzonites; and if, following this idea out into the porphyritic rocks, we should name them according to Brögger's proposal, they would vary from *adamellite-porphyry* to *banatite-porphyry*.

SYENITE-PORPHYRY.

A good example of this type occurs in the intrusive rock at the Florence mine. A variety exposed on the hillside above the mine opening shows a purplish chocolate-colored rock, of rather dense character, spotted with pale-yellow tabular feldspars. These feldspars are orthoclase, and the groundmass is of trachytic structure, with altered and decomposed hornblendes. Rocks of this type, more or less altered, occur in several places in this region.

The rock which forms the summit of Big Grassy Peak may be taken as a type which shows affinities toward the diorites. It is brownish-gray, thickly crowded with feldspar phenocrysts and speckled with black prisms of a ferromagnesian mineral. The microscope shows both augite and hornblende to be present. The augite is in part a green diopside, which varies into a deep-green ægirite-augite. The hornblende, which is partly resorbed, has the following optical scheme: $\mathfrak{c}$, deep green with olive tone; $\mathfrak{b}$, pale leather-brown; $\mathfrak{a}$, pale leather-brown; absorption strong. $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$.

This variety of hornblende occurs in a number of the rocks of this area. The feldspar phenocrysts are mainly orthoclase, but a very considerable quantity of andesine is present. These minerals lie in a groundmass of flakes of alkali feldspar with some quartz; a little titanite, iron ore, and apatite complete the list of minerals.

Rocks that seem to be of this type occur commonly throughout the mountains; the dikes and sheets on Elk Peak appear to belong to it, as well as portions of the Gold Hill intrusive mass on its southern edge.

The brownish color of these rocks, with the strong mottling of the prominent white feldspars, serves to distinguish them from the next type. A most interesting feature in connection with this type of Big

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[1] Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol, 1895, p. 21.

Grassy Peak is that the great Judith Peak-Red Mountain intrusion has on its periphery a facies consisting of this type, while the interior of the mass, as far as it is yet exposed, is the rhyolite-porphyry previously described. It thus appears to show a distinct, though slight, differentiation border.

DIORITE-PORPHYRY.

This is illustrated by the rock which forms the talus blocks and masses on the southwest side of Maiden Peak. The rock is very light colored, with numerous phenocrysts, large ones of alkali feldspar, and smaller, much more numerous ones of plagioclase, which is variable, but may be as basic as andesine, with black prisms of hornblende embedded in a fine groundmass, which the microscope shows to be made up of alkali feldspar and quartz, generally arranged in a peculiar micropoikilitic structure. The rock is apt to be altered. Many of the intrusive sheets in the mountains appear to be of this type. It seems to be that composing the masses of and around Bald Butte.

Another variety of this diorite-porphyry is that which forms the mountain mass east of Ross Peak, of which Cone Butte is the northern part. Of this rock Dana[1] says:

> The main constituent of the rock is a triclinic feldspar, as revealed by a thin section under the microscope, though occasional crystals of orthoclase of greater size may be observed. Hornblende follows next in order, the crystals being very distinct; and, further than this, magnetite plays an important rôle—this is distributed more generally than is common in similar rocks and is seen by the microscope as extremely minute grains whose metallic character is revealed only in reflected light. These particles of magnetite have suffered alteration to a considerable extent, and the feldspar is often stained red and yellow in a ring about them by the oxidized iron. It is to this alteration that the peculiar red color of the talus on the sides of the hills, as seen from a distance, is undoubtedly due.

The rock is rather dense and compact, with numerous small phenocrysts of andesine and larger, less numerous ones of orthoclase embedded in a very fine-grained groundmass of alkali feldspar with a very little quartz and stained with iron hydroxide. Phenocrysts of hornblende are present, more or less resorbed, and shreds of hornblende appear scattered through the groundmass. A little iron ore and apatite complete the list of minerals.

The rock of the mass on the west side of Ross Pass, composing Lewis Peak, is of the same character but somewhat fresher.

Other types of these diorite-porphyries and syenite-porphyries might be mentioned, but the above is sufficient to give an idea of the most important occurrences and to furnish descriptions by which all of them may be readily classified. It is believed, also, that sufficient has been said to show the transition from the syenite to the diorite family and the intermediate position of many of the types.

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[1] Report of a reconnaissance, etc. (see footnote on p. 545), p. 97.

PHONOLITE FAMILY.

In addition to the types of rocks previously described as occurring in the Judith Mountains, there are a large number of intrusive sheets and dikes of alkaline types—that is, rock in which the percentage of silica is lowered and a proportionate increase of alumina and the alkalies has forced some silicate to form, in addition to feldspar, which is richer in alumina and alkalies and poorer in silica than the latter. These rocks are also deficient in lime, magnesia, and to some extent iron, and they are thus members of that family of rocks that are nephelite-syenites when granular, phonolites when fine grained and porphyritic. They belong, moreover, most of them, to that subclass of phonolites characterized by a considerable amount of the soda-iron pyroxene, ægirite, and have in consequence, as a rule, a greenish tinge and greasy luster, this becoming more pronounced as the rocks become denser in grain, until they are tough, dense rocks of a dark grass-green color. This variety of phonolite is known as *tinguaite*, and hence these rocks are chiefly tinguaite and tinguaite-porphyry; but in a few instances the rocks are so much coarser in the grain of the groundmass (the ægirite, instead of being thickly disseminated in microscopic needles as a coloring matter, being condensed in larger prisms, so that the green color is largely lost) that the rock can no longer be called a tinguaite, but is really a very fine-grained porphyritic nephelite-syenite or, probably still better, an ægirite-syenite-porphyry, since the actual amount of nephelite in the rocks is small and the mineral is to be considered as accessory rather than as a component of equal importance with the feldspars. Thus the rocks lie between the classes of the alkali syenites and nephelite-syenites.

ÆGIRITE-SYENITE-PORPHYRY.

There appear to be three important occurrences of this type, in each case forming a thick intrusive sheet. The first is intruded in upturned Cretaceous beds on the southeast side of the Cone Butte Mountains, between the heads of Edwards Creek and the east fork of Ford Creek, and has been described in the previous chapter (pp. 549–550). The rock is of a grayish color, weathering rather brown, and has a strong tendency to split into thin plates, owing to pronounced parallelism in flow structure of the large quantity of very thin tabular feldspar phenocrysts which it contains. These are embedded in a fine-grained groundmass, which, however, is easily perceived to be granular by the eye alone and which contains numerous small black prisms of augite.

Another occurrence of this rock is found in a thick sheet intruded in upturned Cretaceous strata in the spur next east of Maginnis Peak and on the east side of the east fork of Maginnis Creek. It is referred to in the previous chapter (p. 541). The rock has a rather fine, dense groundmass of a pale gray-green color, speckled with black prisms of augite, and in this are embedded large feldspar phenocrysts, which are thickly crowded. The rock furnishes a transition to the denser, greener tinguaites.

The third occurrence is that of the Cemetery Hill below Maiden. It is not quite certain whether this is an intruded sheet or an eruptive mass, but it is probably the latter. On a surface of fresh fracture the rock is of a gray color with a tone of green. It is distinctly granular to the eye alone, the average size of the smaller components reaching perhaps 0.5^{mm}. They consist of feldspars of a gray color, a feldspathoid of a pinkish tone, which is present in small amount, prisms of a black augite, which vary greatly in size, and a small quantity of a fibrous zeolite. In this lie embedded tabular feldspar phenocrysts, thickly crowded, which are of all sizes from 20^{mm} down. The section of this rock shows that the black augite is ægirite-augite, with an exterior mantle of ægirite and often with diopside cores; that the feldspar is entirely an alkali feldspar, showing various interesting features, and somewhat kaolinized. A considerable quantity of an isotropic mineral is also present, which shows occasionally faint optical anomalies and which may be analcite, perhaps in part sodalite. A fuller petrographic and chemical investigation of these types will undoubtedly reveal a number of interesting details.

These types lead us by a greater compactness of groundmass into the tinguaites, to be next considered.

TINGUAITE-PORPHYRY.

This type occurs in large numbers in the northeastern part of the district. It has not been found in that portion of the mountains which lies south of the dividing line of Maiden Canyon and upper Warm Spring Valley. It occurs entirely in the shape of dikes and sheets. The former cut the intrusive masses of the Judith Peak-Red Mountain massif, the Elk Peak mass, and that of the Cone Butte Mountains in all directions, while the intrusive sheets have been found almost entirely in the Benton group. When fresh these rocks are hard, tough, very dense, dark green, with quantities of light-colored, white, or glassy feldspar phenocrysts scattered through them in all directions. These feldspars are usually crowded. They are generally tabular, sometimes arranged in parallel lines, indicating flowage in the dike or sheet, and in that case parallel with the walls and sometimes scattered without direction or orientation. They vary greatly in size in the different occurrences—from very minute ones 2^{mm} or 3^{mm} long to those of huge dimensions, whose thick tables show surfaces as large as the palm of one's hand, an instance of this kind occurring at the mouth of the canyon of West Armell Creek, as described on page 524. In general they average from 0.5^{mm} to 10^{mm} across.

As this rock type is a rare one and yet is a very common and prominent one in this district, it seems well to select one occurrence and give a somewhat detailed account of it, in order to present one description which will serve as a basis of comparison for all the others. For this purpose a specimen of the dike which lies with a north-south trend in the saddle between Cone Butte and the triangulation point south is selected. This dike is mentioned by Dana and Grinnell,[1] who give the following account of it:

> The descent from Cone Butte was made by way of the deep ravine which separates it from the trachytic hills to the south. The white trachyte is carried down nearly to the gap, where we passed a transverse dike, east and west in direction, of a hard green trachyte, with a cubical fracture breaking into large blocks. . . . This is probably a later dike, subsequent to the formation of the other hills. This trachyte, as well as that of Cone Butte, was found in fragments abundantly over the prairie, even to a distance of 15 miles from the mountains. It is characterized by crystals of a glassy orthoclase, which give it a porphyritic structure. Under the microscope these crystals are found to be more or less clouded, in consequence of incipient alteration; this is also shown by the indistinct color obtained in polarized light. Accompanying the large crystals of orthoclase are smaller thin-bladed crystals [of orthoclase] in great numbers. The other essential constituent is the hornblende, which is seen in simple distinct prisms; it has a deep-green color, and is strongly dichroic. No quartz was observed. The most interesting feature of the rock is the green base, which, under a low magnifying power, seems to be without structure, but, when magnified highly, is resolved into countless minute, acicular crystals jumbled together in a confused mass.

The hornblende mentioned is, of course, ægirite, which, in the condition of petrography at that time, was not distinguishable from it; so also are the needles mentioned as being in the base. This, so far as we know, is the first tinguaite which has ever been described.

The writer owes to the kindness of Prof. E. S. Dana an opportunity to examine and study the specimen mentioned above, and finds it to coincide with examples collected by himself. A previous study and analysis[2] of the rock had been made, the results of which are here given.

Megascopic characters.—In a dense, compact, green (dark grass-green without tone of gray) groundmass lie numerous feldspar phenocrysts of tabular and columnar form, but rather stout habit, from 10^{mm} in size down. Besides these there are many very much smaller black prisms of augite. The rock has a rather platy fracture.

Microscopic characters.—In thin section the large feldspars are seen to be somewhat altered; they present the varying, mottled character of anorthoclase, but there are areas which are perfectly homogeneous and with orthoclase character. It would appear as if this variable character was due to a breaking up of the compound molecule of anorthoclase into albite and orthoclase. The phenocrysts of augite are of clear green pleochroic ægirite-augite, with ægirite mantle.

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[1] Report of a reconnaissance, etc. (see footnote on page 545), p. 97.

[2] The Bearpaw Mountains of Montana, by Weed and Pirsson: Am. Jour. Sci., 4th series, Vol. II, 1896, p. 192.

The groundmass in which these minerals lie is made up of small feldspars, minute areas of nephelite, others of an isotropic mineral, the whole mingled with considerable quantities of secondary zeolites and pinned through and outlined in every direction by countless slender needles of ægirite, which shrink to the most minute size perceptible with high powers. They frequently outline small sections of a round shape, now converted into zeolites. The structure may be said to be allotriomorphic as nearly as anything. The character of the rock as seen in thin section is shown in Pl. LXXXI, *A*.

Chemical analyses.—The analysis of this rock shows the composition given in Column I of the following table:

Analyses of tinguaites.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Ia.
SiO_2	57.63	57.46	56.58	54.46	58.89	53.21	55.90	52.91	0.960
Al_2O_3	17.53	15.40	19.89	19.96	19.67	22.02	19.00	19.49	.170
Fe_2O_3	3.46	4.87	3.18	2.34	1.79	....	2.05	4.78	.022
FeO	1.18	.87	.56	3.33	1.23	4.18	2.54	2.05	.016
MgO	.22	1.37	.13	.61	.17	.91	1.10	.29	.006
CaO	1.35	2.59	1.10	2.12	1.31	1.33	3.12	2.47	.024
Na_2O	5.80	5.48	10.72	8.68	4.41	10.37	8.49	7.13	.093
K_2O	9.16	9.44	5.43	2.76	11.00	6.41	5.41	7.88	.098
H_2O	3.22	.91	1.77	5.20	1.11	.81	(?)	1.19	....
TiO_2	.23	.60	(?)	trace	(?)	.35	1.45	none	....
Cl	.08	.20	(?)	(?)	(?)	(?)	(?)	.53	.002
P_2O_5	trace	.21	(?)	(?)	(?)	(?)	(?)	trace	....
SO_3	....	.13	....	....	....	....	....	.52	....
CO_2	....	.13	....	....	....	....	trace	none	....
Fl	....	trace	....	....	....	....	....	X.48	....
MnO	trace	trace	.47	trace	.59	.42	.28	.44	....
BaO	not det.	.60	....	....	....	....	....	....	....
SrO	not det.	.16	....	....	....	....	....	.09	....
Li_2O	trace	trace	....	....	....	....	....	trace	....
	99.86	100.42	99.83	99.46	100.17	100.01	99.34	100.25	....
O Cl	.03	.05	....	....	....	....	....	.13	....
	99.83	10 0.37	....	....	....	....	....	100.12	....

I. Tinguaite-porphyry dike, Cone Butte, Judith Mountains, Montana; L. V. Pirsson, analyst. Weed and Pirsson, Am. Jour. Sci., 4th series, Vol. II, 1896, p. 192.

II. Tinguaite-porphyry dike, Bean Creek, Bearpaw Mountains, Montana; H. N. Stokes, analyst. Weed and Pirsson, Bearpaw Mountains, Am. Jour. Sci., 4th series, Vol. II, 1896, p. 192.

III. Tinguaite dike, Hedrum, South Norway; G. Paykull, analyst. Brögger, Grorudit-Tinguait Serie, p. 113.

IV. Tinguaite dike, Njurjawpachk, Umptek, Kola; K. Kjellin, analyst. Ramsay and Hackmann, Neph. Syen. Gebiet Kola, Fennia II, No. 2, 1894, p. 158.

V. Tinguaite ("Leucit tinguait vitrophyr") Picota, Serra de Monchique, Portugal; A. Zilliacus, analyst. Kraatz-Koschlau and Hackmann, Eleo. Syen. der Serra de Monchique, Tscher. Mitth., vol. 16, 1896, p. 252.

VI. Tinguaite-porphyry dike, Foia Serra de Monchique, Portugal. Ibid.

VII. Mica-tinguaite. Ibid.

VIII. Leucite-tinguaite, Magnet Cove, Arkansas. J. F. Williams, Ig. Rocks, Arkansas, 1890, p. 287.

Ia. Molecular ratio of oxides in I.

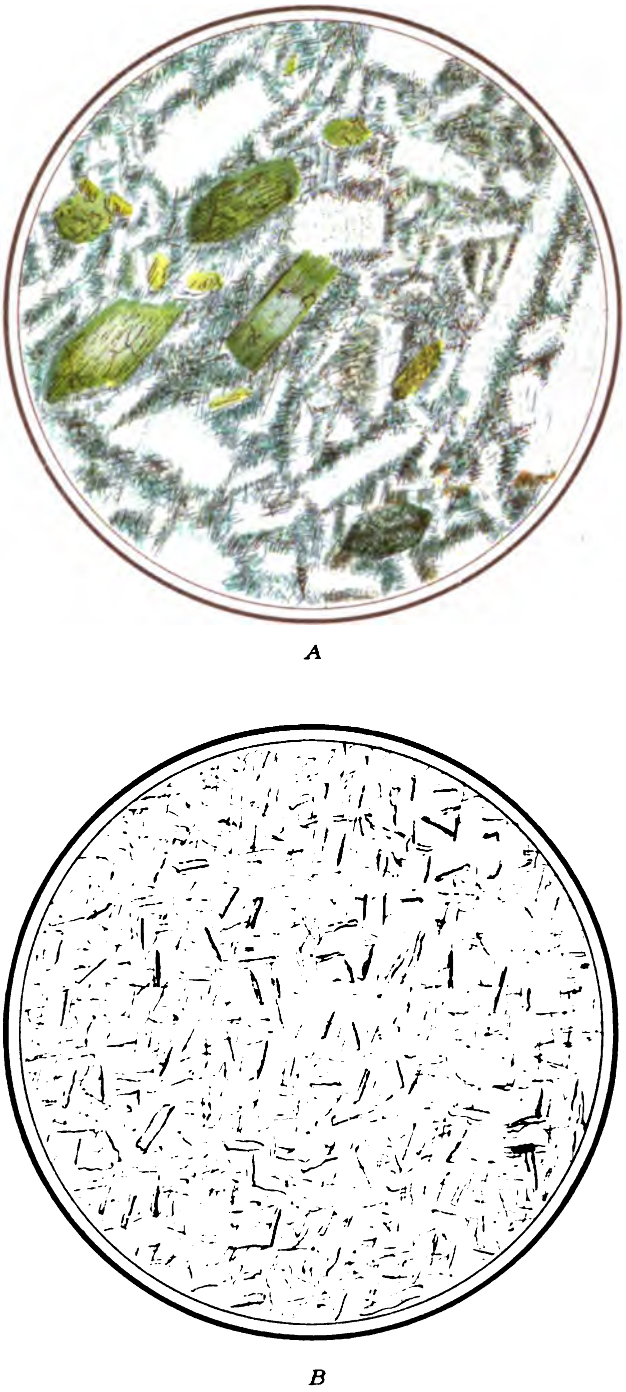
A comparison of this analysis with analyses of other tinguaites from various parts of the world shows that it possesses all of the type characters. In its relative proportion of soda to potash it agrees very closely with tinguaite from the Bearpaw Mountains, another island mountain group whose peaks on a clear day can be seen from the Judith Mountains. The peculiarity of these rocks lies in the large amount of potash they contain, which is, as our studies of the central Montana rocks show, a regional peculiarity, a feature of this "petrographical province" which is akin to the strong soda content of the alkaline rocks of southern Norway.

A study and comparison of the molecular ratios given in Column *Ia* of the preceding table shows, in connection with the minerals made out by microscopic study, that the rock has the composition seen in the following table:

Mineral composition of tinguaite.

	Ægirite.	Diopside.	Orthoclase.	Albite.	Nephelite.	Sodalite.	Calculated.	Found by analysis.
SiO_2	2.69	2.69	35.35	12.89	3.71	0.43	57.76	57.63
Al_2O_3			10.11	3.69	3.18	.37	17.35	17.53
Fe_2O_3	3.46						3.46	3.46
FeO		1.18					1.18	1.18
MgO		.22					.22	.22
CaO		1.24					1.24	1.35
Na O	1.36			2.22	1.92	.30	5.80	5.80
K_2O			9.16				9.16	9.16
Cl						.08	.08	.08
Total	7.51	5.33	54.62	18.80	8.81	1.18		

The quantity of water furnished by the analysis shows the very considerable amount of zeolitic alteration the rock has undergone. Fortunately, however, in these zeolitic formations the changes are in the majority of cases merely a shifting of the molecules among themselves with the addition of water. Matter (except water) is usually neither added to nor subtracted from the rock, and the proportions of the elements given by analysis in such cases show those of the original



THIN SECTIONS OF PHONOLITIC ROCKS (TINGUAITE)
FROM THE JUDITH MOUNTAINS.

L.V.P. del.

A. **Tinguaite-porphyry dike at Cone Butte, collected by E. S. Dana. Plain polarized light. Phenocrysts of ægirite-augite with ægirite rims and of anorthoclase or soda orthoclase in a ground mass of the same feldspar with nephelite and a little altered sodalite penetrated by innumerable needles of ægirite. Multiplied by 36; actual field 2 mm.**

B. **Dense non-porphyritic tinguaite; sheet in Benton shales, south side of Cone Butte mountain mass. Fine prisms and needles of ægirite-augite and ægirite mixed with small laths of alkali-feldspar and a little nephelite. Multiplied by 63; actual field 1.2 mm.**

unaltered rock. Of course cases are common where this is not so, but such are readily seen in the change in the character of the rock itself. We may therefore disregard the water in making this calculation, and refer the oxides to those mineral molecules which are present and which we know have been the ones altered. The close agreement between the calculated and the theoretic composition is proof of the correctness of the composition assigned.

The ægirite-augite, then, has the following composition, deduced from the analysis:

Theoretic composition of ægirite-augite.

		Molecules.	
SiO_2	41.1		
Fe_2O_3	26.9	$\mathrm{Na}\dddot{\mathrm{Fe}}\mathrm{Si_2O_6}$	219
FeO	9.2	$\mathrm{Ca}\ddot{\mathrm{Fe}}\mathrm{Si_2O_6}$	164
MgO	1.7	$CaMgSi_2O_6$	55
CaO	10.5		
Na_2O	10.6		
	100.0		

Or, in other words, it consists of a mixture of exactly one molecule of diopside-like pyroxene with one of ægirite.

NONPORPHYRITIC TINGUAITE.

Description.—In addition to those tinguaites which contain large phenocrysts of feldspar there are one or two cases where these are entirely lacking and the rock becomes a typical tinguaite. The best example of this is seen in the sheet intruded in Benton shales on the south side of the Cone Butte Mountain mass, and which is mentioned in the latter part of the preceding chapter (page 552). This, like the groundmass of the rock already described, is without any porphyritic crystals; it is perfectly dense, dark green, and its character is shown in Pl. LXXXI, *B*. A somewhat similar rock is found in the bowlders in the park at the head of Spotted Horse Gulch and on the south side of Big Grassy Peak. It contains a few scattered phenocrysts, however, and brown melanite was noted in it. The same mineral occurs in other rocks of this class. In fact, every transition from tinguaites without phenocrysts to those with phenocrysts of great size, thickly crowded, may be found. While it is clear that in many cases the phenocrysts have been brought up to the place where they now are from greater depths, in other cases the evidence is against this and points to their formation in place.

Weathering.—While these rocks often assume a dark, rusty color, due, perhaps, to change of the iron from ferric silicate to hydroxide, it is noticeable in this region that they often weather and bleach, becoming at the same time gradually much lighter in color. In some cases, indeed, the dike has been thoroughly kaolinized and the iron leached out, so that it is now a light-colored clay recognizable only by the feldspar pseudomorphs and characteristic structures it retains. Just what the process is that produces this bleaching and leaching out of the iron is not known, but it is to this that the iron ore accumulations on several of the streams—West Armell, West Maginnis, and Edwards creeks—are due, the tinguaite dikes as well as the large porphyry masses furnishing the material.

Tinguaite border facies.—In several localities on the edge of the great Judith Peak-Red Mountain intrusion, as, for instance, near the Chicago prospect mine, between the head forks of West Maginnis Creek, the porphyry appears to pass into a tinguaitic phase, with tabular feldspar phenocrysts and greenish groundmass; but unfortunately the relations are obscure from the broken-down and altered character of the exposures; and so, while the authors believe this to be the case, they do not feel that it is certainly proved. A similar case was noted by Mr. Weed in the Little Rocky Mountains and mentioned in our joint paper on that region.[1]

GENERAL PETROLOGY.

From what has been said in the foregoing pages of this chapter it can be readily seen that the Judith Mountains present types of igneous rocks which fill only one portion of the list of groups—the acid-feldspathic half. They range from syenite to granite-porphyry, but the basic types, the pyroxenic rocks, are wanting. Nevertheless, they appear to occur in most of the varied modes of intrusions, as laccoliths, dikes, sheets, and stocks, which cut across the sedimentary series. If one believes in the theory of differentiation one must think that the basic types have not been erupted toward the surface and are still concealed below. However this may be, there is still a considerable variety shown by the rocks that occur. They range from dioritic into syenitic types, and on into phonolitic types, with silica remaining about the same, the variation being effected by the change of iron, magnesia, and chiefly lime, as against alumina and alkalies. In another direction they vary in the silica and pass from syenite to granite-porphyry.

ORIGIN OF DIKES AND SHEETS.

By far the most interesting feature, in a petrologic way, of this mountain group, lies in the occurrence of the phonolite (tinguaite) dikes and sheets and their relations to the other rocks. First, it is a noteworthy fact that these rocks do not occur in the mountains south of the divisional line of Maiden Canyon and upper Warm Spring Creek Valley. They are thus confined entirely to the northern part of the mountains. Further, the dikes are confined almost entirely to the large bodies of igneous rocks, which they cut in all directions and without system, so far as can be told. The intrusive sheets, on the other hand, are found only in the Cretaceous beds—in the black shales of the Benton group almost exclusively. It is also noteworthy that these sheets generally curve round conformably with the beds domed up by some laccolithic mass. If we therefore assume from this fact that these intrusive sheets antedate the intrusion of the porphyry which uplifted or broke through the sediments, we must then assume that there have been two periods of the eruption of phonolite magmas—the first into the Cretaceous beds, at that time horizontal; the second producing the dikes which cut the intruding masses of porphyry which have domed up the strata. While this seems plausible, there are several difficulties in the way of accepting it. The phonolites, whether in sheets or dikes, are exactly alike, and it is hard to believe that two periods of intrusion, separated by a long interval during which a vast amount of entirely different magma was intruded, should have produced such highly differentiated, peculiar magmas exactly alike, one of which appears wholly in the form of dikes and the other in the form of sheets. Again, on this assumption it is difficult to see why all the sheets are in Cretaceous and all the dikes cut the porphyry masses; it would seem most logical that the dikes should have cut, not the porphyry, but the sediments surrounding the porphyry masses. And, again, why should laccolithic masses be cut by dikes of an entirely different kind of igneous rock? Any theory which explains the origin of these phonolitic intrusions must also explain these points.

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[1] Weed and Pirsson, Geology of the Little Rocky Mountains: Jour. Geol., Vol. IV, 1896, p. 419.

It seems to us that all of these facts may be explained by the assumption of a theory by which it is supposed that after the intrusion of the magmas took place, processes of differentiation of some kind produced in the still liquid masses smaller bodies of phonolitic character. This assumption seems warranted by the border facies of somewhat phonolitic type which have been noted in several places, and by the fact that such "laccolithic differentiation" has of late been shown to be a rather common process under proper conditions. The general character of the main porphyry masses warrants the assumption that differentiation taking place in them would produce bodies of alkaline magma.

By "differentiation" is here understood a *result*, the separation of an original fluid into fluids of a different chemical composition, not a *definite kind of a process*. Be the *process* what it may—diffusion, convection currents, chemical repulsion, or some other process yet to be discovered—the *result* is beyond doubt, and it is that with which we are immediately concerned.

As these main masses cooled and solidified, there must have been a large amount of contraction, and such contraction may have forced these still liquid phonolitic magmas through fissures in the main masses, producing dikes; while the settling down of the cover would have relieved the compression of the arching sediments, especially along the outer spring of the arches, and permitted the magmas from the dikes to penetrate the light beds, forming intrusive sheets, which would have found it easier to penetrate the arching strata of the easily split shales than to cut across them as dikes. Possibly they did both. In the southwestern half of the region all of the laccoliths are below the massive beds of the Paleozoic series, and the load may have been too great to permit of this secondary upthrusting of material; while in the northern and eastern half the intrusion took place above the Paleozoic, either in the Jurassic beds or toward the base of the Cretaceous section, with but one exception, that of Elk Peak, which appears to have taken place just below the massive bed at the top of the Carboniferous. The fact, also, that this massive bed is cut by phonolite dikes seems to furnish additional confirmation to the theory. The light, easily split horizons of the Benton shales would furnish an admirable locus for the conversion of the ascending dikes into sheets.

It is probable, however, that the geographic distribution of the phonolite dikes and sheets depends much more on a variation of chemical composition of the original intruding magmas than on local physical conditions.

A case which seems to favor this explanation for the mode of occurrence of the dikes and sheets is found on the south side of the Cone Butte laccolith, where, on the crests of several spurs, phonolitic dikes run out from the main porphyry mass, cutting the sediments until the Benton beds are reached, when they diverge into intrusive sheets and end. This occurrence is shown on the map (Pl. LXXV), and has been already described (p. 552).

While this theory of differentiation and contraction to explain the origin of the dikes and sheets is open to objections, it seems to the writer that it serves better to explain and harmonize the various facts observed than any other which has suggested itself.

SIZE OF GRAIN NOT DEPENDENT ON DEPTH.

An interesting feature presented by the laccolithic masses is that the granularity of the rocks, their degree of crystallization, bears no relation to the depths at which they have been intruded. The laccoliths in the Cambrian show the same dense grain as the sheets intruded in the upper members of the Cretaceous. This is in accord with the facts adduced by Cross[1] for the laccoliths of the Colorado Plateau. On the other hand, chemical composition has been a most important factor, the more basic phonolitic magmas, though intruded in the Upper Cretaceous in small masses, being in some places quite granular rocks, while the vastly larger masses of the great laccoliths in the Cambrian, composed of very acid types, are dense felsitic porphyries. This is an illustration of the general rule that, other things being equal, the more basic a magma the more granular and the coarser its degree of crystallization.

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[1] Laccolitic mountain groups, etc.: Fourteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 230.

SUMMARY.

The igneous rocks of the Judith Mountains are of acid-feldspathic character, and are very like those characteristic of other laccolithic areas. They comprise granite-porphyry, syenite, syenite-porphyry, and diorite-porphyry in the main masses, with dikes and sheets of the variety of phonolite-porphyry called tinguaite-porphyry. While the intrusion of the former rocks has taken place according to well-known processes, it is believed that the phonolite-porphyry was formed by some process of differentiation in the main masses and was injected into the sediments above them by what may be called secondary intrusion.

The granularity of the rocks depends on their chemical composition and not on the depth at which they have been intruded.

CHAPTER VI.

By L. V. PIRSSON.

DYNAMIC AND STRUCTURAL GEOLOGY.

INTRODUCTORY.

In his now classic work upon the geology of the Henry Mountains Gilbert[1] says:

> The Henry Mountains are not a range and have no trend; they are simply a group of five individual mountains separated by low passes and arranged without discernible system. * * * The Henry Mountains are similar among themselves in constitution. They all exhibit dome-like uplifts; they all contain intrusive rocks, and their intrusive rocks are all of one lithologic type. They are, moreover, quite by themselves; the surrounding country is dissimilar in structure, and there is no gradation or mingling of character. Thus similar and thus isolated, it is natural to regard the mountains as closely related in origin, to refer their trachytes to a common source, and to look for homology in all their parts.

This general statement, written for the Henry Mountains, might just as well, with a few minor exceptions, have been written for the Judith Mountains. While they have a longer axis and may thus be said to have a trend, they are not a mountain range in the ordinarily accepted use of that word, since they owe their elevation, so far as can be ascertained, not to any general movement over the area, but entirely to disturbances produced by local intrusions of igneous rocks.

POSITION AND NUMBER OF JUDITH MOUNTAIN LACCOLITHS.

The Judith Mountains, in fact, consist entirely of a group of laccoliths of varying size, many of which are of perfectly normal, symmetric character, while others are asymmetric, and these pass into intrusions of porphyry into the strata, which are of the most irregular character and are laccolithic only in the sense that they certainly possessed a cover of sedimentary material under which the fluid mass hardened and crystallized. No evidence of any kind has been seen which would tend to support the view that the mountains owe their elevation to any general folding of the strata or that the horizons of strata lower than those lifted on the backs of the laccoliths are in any other than a horizontal and undisturbed condition.

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[1] Report on the Geology of the Henry Mountains, by G. K. Gilbert, 1877, pp. 2 and 52.

The number and position of the laccoliths composing the Judith Mountains are seen in the ground plan shown in the figure below (fig. 51). In this the laccoliths are represented as circular in ground plan; some actually are circular; most are probably more or less so, while one is certainly not circular but oval in ground plan. The plan is, of course, merely an ideal one, to give an indication of the relative size and position of the laccoliths.

From this figure it can be seen that the main features of the mountain group are formed by six principal laccoliths and three intrusive masses of porphyry. The distinction, of course, between a principal and subordinate laccolith is purely arbitrary, dependent on the size. Of these six laccoliths, two (A and B) are known to be intruded in the Cambrian shales and are only partially denuded; F, the only one in the Mesozoic, is almost wholly denuded, while the others are yet concealed by their Paleozoic covers. The remaining subordinate laccoliths are partly in the Paleozoic and partly in the Mesozoic.

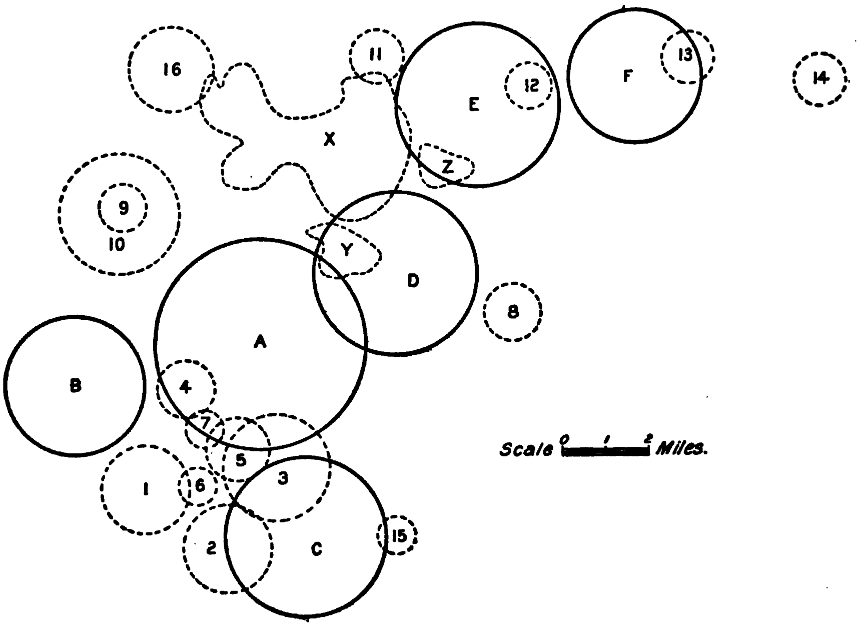

FIG. 51.—Ground plan of Judith Mountain laccoliths. A, B, C, D, E, and F, principal laccoliths, doming up Paleozoic strata, except F, the only principal laccolith in the Mesozoic. A, Alpine; B, Burnett; C, Flat Mountain; D, Crystal Peak; E, Elk Peak; F, Cone Butte Mountains; 1, 2, 3, 4, 5, subordinate laccoliths in Paleozoic horizons; 7-16, subordinate laccoliths in Mesozoic horizons. X, Y, Z, intrusions of porphyry: X, Judith Peak-Red Mountain mass; Y, Gold Hill intrusion; Z, Maginnis Peak.

They also exhibit every stage of denudation, grading from those like Lewis and Lookout peaks (Nos. 12 and 13) which are almost wholly deprived of their covers, through intermediate stages like the Warm Spring laccolith (No. 9) illustrated in fig. 45, p. 519, to simple anticlinal domes, like those of Deer Creek (No. 16) and Fort Maginnis (No. 8). In the latter case, since the porphyry is not yet exposed, the horizon at which it is intruded can, of course, only be surmised; but knowing the diameter of the dome on the surface, the lowest beds that are exposed in it, and the thickness of the various sedimentary horizons, it is easy to calculate at what depth the porphyry must lie, and by the aid of the dips to determine the shape of the upper portion of its mass.

PROOFS OF THE LACCOLITHIC CHARACTER OF THE INTRUSIONS.

Evidences of the character of the intrusions are everywhere manifest, and, indeed, to the geologist trained by actual field study an inspection of the geologic map at once suggests the structure. Also, all of the proofs mentioned by Gilbert[1] are present in the Judith Mountain laccoliths and may be summarized as follows: (1) The associated strata contain no igneous rocks in the material composing them. (2) The porphyry is always compact and of intrusive, never of extrusive, character. (3) The inclination of the strata shows that they could not have been subsequently deposited upon the domes of igneous rock; and most important of all, the igneous rocks have baked and altered the strata above and, in those cases where the base is exposed, below them. To present proofs for the existence of laccoliths at this stage of geologic history is, however, a work of supererogation; only those who have no adequate knowledge of the subject and have not seen good examples hesitate to believe in them.

With regard to those laccoliths in which the igneous masses doming them have not yet been exposed, it can only be said that since laccoliths in every possible stage of denudation are found in the region, one is led by gradual steps to the inevitable conclusion that these are also due to the same cause. They have in absolutely all respects the characters that the domes whose laccolithic nature is revealed would have if restored to the same stage; and as no other geologic agency of any kind is seen in the district to account for them, one is led to believe, from the continuity of nature itself, just as firmly that these domes are due to laccoliths, yet concealed, as in those cases where the laccoliths have been exposed.

Similar domes of stratified beds are also described by Gilbert in the Henry Mountains, and more recently Russell[2] has ascribed to such agencies domes occurring in the Black Hills of South Dakota.

HORIZONS INVADED.

Two principal stratigraphic horizons have been the seat of igneous intrusions, the Cambrian shales and those in the Jurassic just above the Carboniferous. In some cases intrusions have occurred in the

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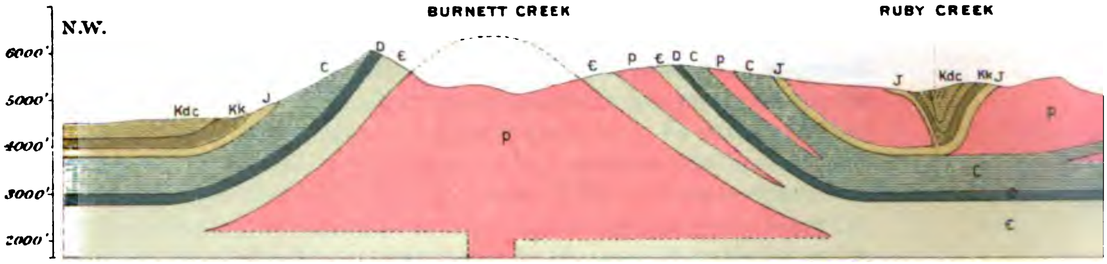
[1] Geology of the Henry Mountains, p. 51.

[2] Jour. Geol., Vol. IV, 1896, p. 21.

U.S.GEOLOGICAL SURVEY



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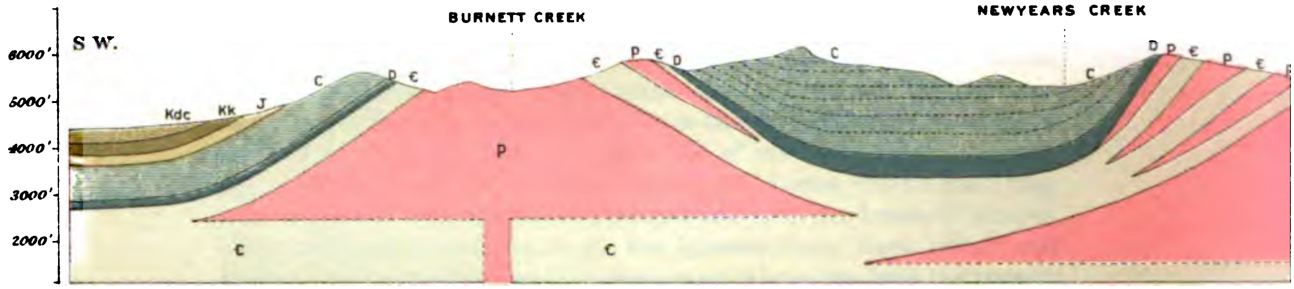

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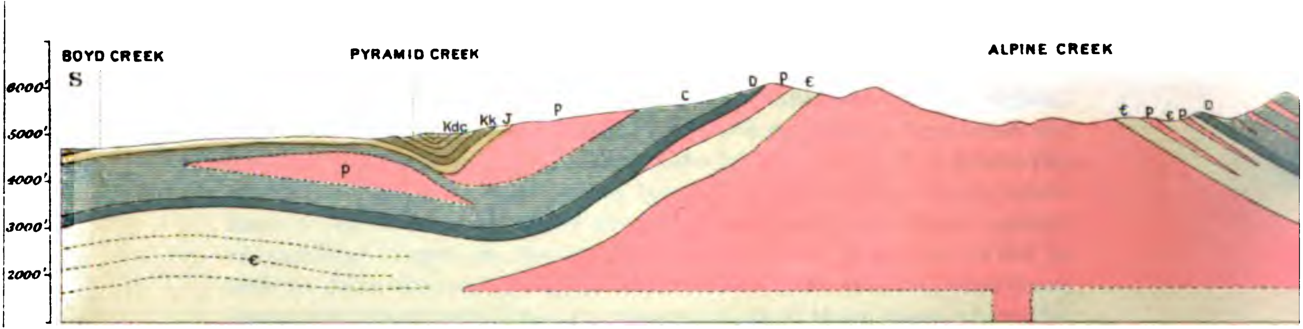

SECTI

CRETACEOUS

Kdc

BENTON FORMATION
Black shales & sandstones
DAKOTA FORMATION
Red clays & sandstones.

■

KOOTANIE FORMATION
Shales sandstone & coal.

JURASSIC

J

Shales, thinly bedded limestones and sandstone.

CARBONIFEROUS

■

Massive bedded limestones.

SIL

DEV

■

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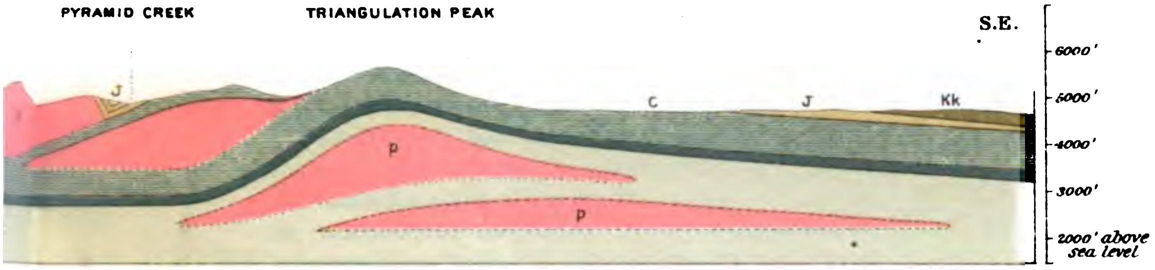
GEOLOGIC SECTION

Sc

1 0

Walter Harvey Weed Geologist in charge.
Geology by Louis V. Pirsson.



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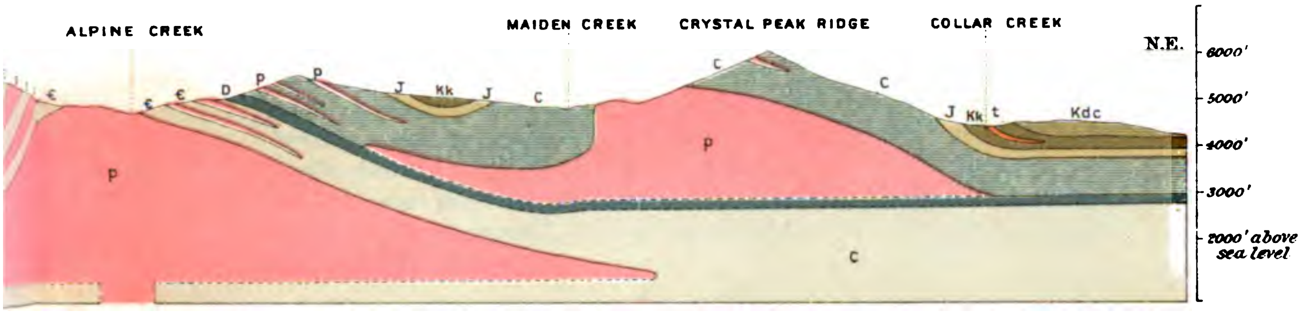

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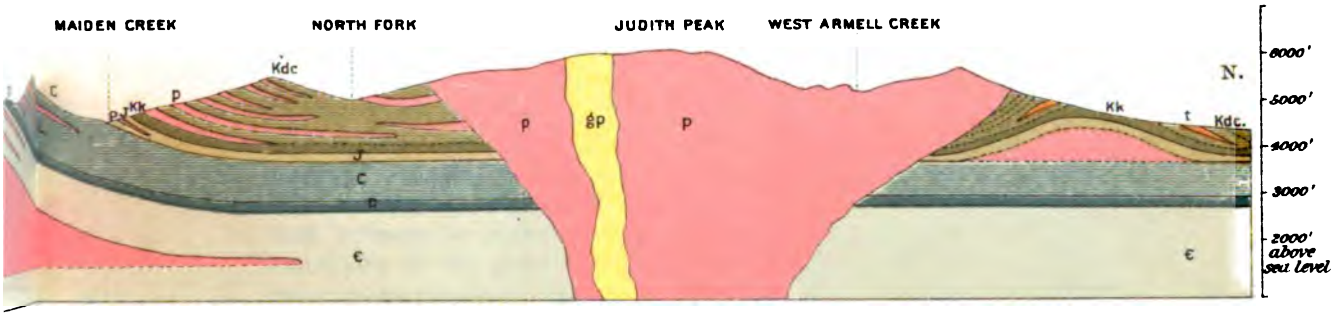

CTION C–C

RIAN ND NIAN

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y bedded stones.

CAMBRIAN

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Conglomeratic limy shales and thinly bedded limestones.

IGNEOUS ROCKS

gp

Granite porphyry

p

Acidic porphyries in intruded sheets.

t

Phonolite (tinguaite) and phonolitic porphyry in dikes and sheets.

IONS, JUDITH MOUNTAINS

ale

2 3 MILES.

JULIUS BIEN & CO. LITH. N.Y.

Cretaceous beds, as in the case of Lookout Peak. A few instances are known where lenticular intrusions have occurred in the massive Carboniferous; but these are in the main more of the character of intrusive sheets attendant upon laccoliths and introduced probably at the same time through buckling of the beds, and are not to be regarded as independent laccoliths. In the case of those which are not yet uncovered and are still under Paleozoic covers, the seat of the intrusion must be conjectural; but by analogy it is assumed that the Cambrian has been the horizon invaded.

The base of the Mesozoic is not only a horizon in which laccoliths occur, but to a very large extent one in which intrusive sheets are also found. This is well illustrated around the outer flanks of the Elk Peak dome, where not only do sheets occur, but these swell out in places into thick lenticular masses which might well be classed as small subordinate laccoliths. It is very clear that these horizons have been selected by the ascending and invading magmas because of their fissile character and ready penetrability. It is in such shaly horizons that the vast majority of intruded sheets occur, not only here but in other localities as well, and an intruded sheet is the first (and necessary) stage of a laccolith.

GRADATION BETWEEN SHEETS AND LACCOLITHS.

In the Judith Mountains every gradation from intrusive sheets to highly arched laccoliths occurs, and these gradations are well illustrated in the accompanying figures and plates of geologic sections. Since no intrusive sheet is continuous in the sense that a certain sedimentary stratum is continuous, and since the sediments must yield in some direction to allow of its intrusion, it follows that sheets intruded into horizontal strata must have the form of a very flattened plano-convex lens, flat on the bottom because the sediments can not yield to any appreciable extent in that direction, convex on top because they must yield in that one. Thus there is no real distinction between an intruded sheet and a laccolith except in degree of convexity of the upper surface, and any line drawn between them must be an arbitrary one. In a recent article Gilbert[1] has described and figured as a laccolith an igneous intrusion whose degree of convexity is so low that in a small mass it would usually be designated a sheet.

FORMS OF LACCOLITHS.

It will be seen from the figures which have been given in a number of places in this work, representing cross sections of the laccoliths, and also from Pls. LXXXII and LXXXIII, that the laccoliths, as intimated above, vary greatly in the degree of their convexity. This is partly due to the fact that the sections often cut the laccoliths near the outer boundaries, necessarily giving sections of low arch, and partly, as suggested above, to actual variance in the forms of the laccoliths. Judging from those facts which have been observed, and from the known thickness and disposition of the strata, the laccoliths, though they may be very convex on top, yet taper off on their edges and do not end, abutting abruptly against the strata, as Gilbert has, for instance, figured the Hillers laccolith in the Henry Mountains.[1] This is shown in figs. 52 and 53, where both types are represented, the Hillers type being Gilbert's figure with slight modification.

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[1] Jour. Geol., Vol. IV, 1896, pp. 816, 824.

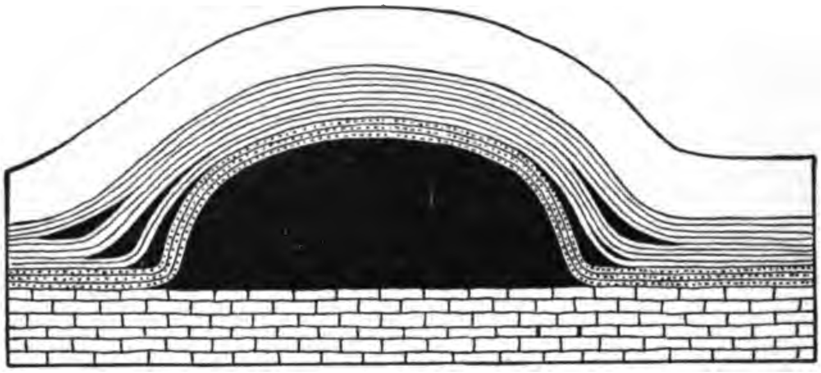

FIG. 52.—Mount Hillers type of laccolith (after Gilbert).

In the Judith Mountains the sheets are of common occurrence in the Lower Mesozoic strata just above the Paleozoic arches, and these, as shown in fig. 53, occur in all transitions to what are really subsidiary laccoliths. Thus in fig. 53 the whole uplift is due not only to the principal laccolith but to the subsidiary ones as well, and such a structure appears to be a compound laccolith. The thickening or compounding of laccoliths in this way and the doming up of the strata are phenomena which are found not only in the Judith Mountains

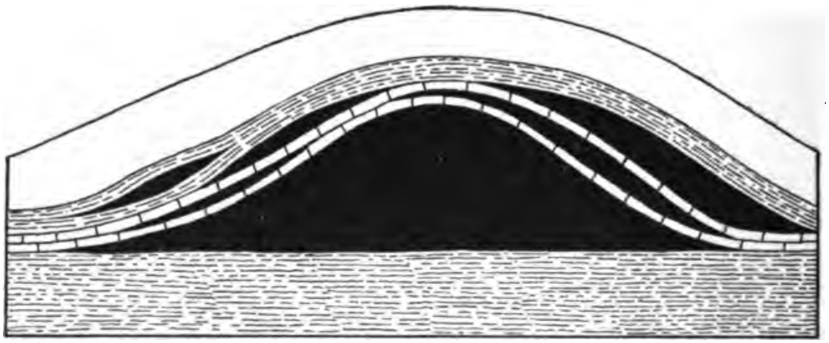

FIG. 53.—Judith Mountain type of laccolith.

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[1] Geology of the Henry Mountains; plate between pp. 31 and 32.

but in other localities as well. Thus the peripheral fringe of intrusive sheets at Castle Mountain, described by the authors,[1] seems to be of a similar nature, and also some of the cases described by Cross[2] in the laccolithic mountain groups of Colorado, especially the La Plata Mountains.

ASYMMETRIC LACCOLITHS.

In some cases the laccoliths are not perfectly symmetrical, but have burst up along several stratigraphic horizons, forcing back the lower sediments into the arch raised by the lighter, upper beds. This is well illustrated by Black Butte, a cross section of which is shown in fig. 49 (p. 555). Such cases furnish transition types to the irregular intruded masses of Maginnis Peak, Judith Peak-Red Mountain, and Gold Hill. Cross[3] remarks that the regular dome shape of the theoretical laccolith can be seldom realized in nature, and describes several asymmetric forms, such as those of Mount Marcellina and the Anthracite Range. It is a question, of course, how far the term laccolith may be applied to irregular intruded masses, but it seems proper to extend it, as Cross has done, to all thick lenticular masses which have domed up the strata and have over the greater part of their area a floor of sediments. One usually thinks of the floor of the laccolith as being at least approximately horizontal, but the thick lenticular masses that lie intruded in the Mesozoic strata and tilted against the Paleozoic domes in the Judith Mountains (illustrated in fig. 53 and in other figures appearing in this paper) are also really laccoliths. In many cases it will be impossible to say whether these may not have been intruded previous to the main laccoliths and tilted by them, or whether they were a contemporaneous filling, as the strata doming up under the main intrusion allowed areas of relief of pressure radially along the spring of the arches. Mr. Weed has recently described doubly convex intrusions as laccoliths in inclined strata.[4]

Russell[5] has recently described some of the igneous intrusions in the Black Hills of South Dakota, and, associated with them, domes in the sedimentary beds, of quaquaversal type, arching up the strata like those in the Judith Mountains. Russell,[6] however, was not inclined to believe that the Black Hills intrusions are of normal laccolithic types, but held these intrusions to be due to plugs of igneous rock forced up into or through the lower horizons of sediments but doming up the higher beds. He does not give any figure to illustrate his idea, and it is not altogether clear just what form he assigns to the uneroded igneous mass; but it is inferred that an occurrence like that of Black Butte, illustrated on page 555, would represent them approximately.

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[1] Geology of the Castle Mountain mining district: Bull. U. S. Geol. Survey, No. 139. 1896, p. 60.

[2] Fourteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 209.

[3] Op. cit., p. 236.

[4] Science, May, 1897, pp. 811-812.

[5] Jour. Geol., Vol. IV, 1896, p. 23.

[6] Op. cit., p. 177.

As we have no sections through these masses, or other formal data showing their relations to the sedimentary beds, it is impossible for one who has not visited the locality to pass any judgment concerning them; but one sees no reasons, from the descriptions given by several observers, why these intrusions may not be, in part at least, of normal laccolithic character. It is impossible to conceive that the tall, shaftlike mass of Mato Tepee (Bear Lodge), with a vertical columnar structure whose columns are several hundred feet long, can be a volcanic plug in a condition anywhere near approaching its original horizontal diameter. The mechanics of the jointing of igneous rocks forbids such a supposition, and we must believe that it represents only a still uneroded fragment, whose vertical walls are produced by the columnar structure of a mass which formerly was of much greater lateral extension and possibly of laccolithic form.

JOINTING IN LACCOLITHS.

In the Judith Mountains the character of the jointing of the igneous rocks appears to depend more on the nature of the rock than on its form or mass. The very acid rhyolite-porphyries or granite-porphyries usually break into extremely small blocks of angular shapes, the syenite-porphyries into blocks of a similar character but considerably larger, while the tinguaite (phonolite)-porphyry forms large, massive, cuboidal blocks or thick plates. Thus one may state that, in this area, the more acid the rock the finer jointing it possesses. There does not seem to be any system to the jointing of the acid porphyries that can be discovered, but in the more basic rocks it approaches a rude columnar structure.

This breaking up into blocks appears to be the character of laccoliths which have been described elsewhere that are also composed of very acid types. In laccoliths or thick sheets of rocks of medium basic nature, however, the character of the jointing appears to depend very much more on the form, size, and character of the intrusion.

Thus in the case of Square Butte, a laccolith in Cretaceous strata some 40 miles to the northwest of the Judith Mountains, the jointing assumes the character of a platy parting parallel to the domed surface.[1] A somewhat similar occurrence, on a much greater scale, is described by Ramsay[2] as occurring in the Umptek Mountain group, which he regards as produced by the erosion of a tremendous laccolith. On the other hand, columnar parting occurs, and this is, indeed, very characteristic for thick sheets or thin laccoliths of very basic rocks. The much jointed, highly crackled condition of these acid porphyries has permitted the circulation of waters through them while they were still heated, and this explains, in a large degree, why they are so greatly altered. It may be that the waters came already heated from below, carrying ore which they deposited in part in the porphyry; or it may be that they received their heat from the porphyry and leached from them the ores they previously contained. This will be mentioned again in the economic portion of this work—the next chapter. The much crackled and frequently decomposed condition of the porphyry is a great aid in mining operations.

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[1] Bull. Geol. Soc. America, Vol. VI, 1895, p. 400.

[2] Das Nephelinsyenit gebiet auf der Halbinsel Kola Fennia, II, No. 2, 1894, p. 81.

DEPTH OF LACCOLITHIC INTRUSION.

The total thickness of the sedimentary beds exposed in the Judith Mountains is about 3,000 feet, and this is the thickness which is now involved in the deepest laccolithic domes. This thickness certainly does not represent the total original thickness of the strata, because laccolithic masses, such as those of the Cone Butte mountain mass, are intruded in the highest beds, and a great thickness must have once rested upon them, otherwise they could not have the form and structure they now possess. The same is true of the intrusive masses of Judith and Maginnis peaks. These are also found cutting the Benton group, the highest beds seen in the mountains, and yet it is clear that over them also once rested heavy covers of sediments. The Niobrara group of the Colorado formation, the southward extension of the Belly River formation of the Canadian geologists, with both groups of the Montana, the Pierre and Fox Hills, may all have been once present, while most of them undoubtedly were. The Laramie is regarded by Mr. Weed as probably not present. These sediments unquestionably were several thousand feet in thickness, and by that much the mountains have suffered from denudation in addition to what they have lost of the sediments now represented. They must have had originally a height of upward of 10,000 feet above sea level. This would also tend to show that the intrusions must have taken place toward the end of the Cretaceous or beginning of the Tertiary.

CONTACT METAMORPHISM.

This phenomenon attending the intrusion of igneous rocks into the stratified ones varies locally very much in the Judith Mountains. There is a good deal of it present, and yet one may say in general terms that the laccoliths have not altered the beds with which they come in contact to the excessively hard, dense rocks usually seen in connection with the cores filling volcanic throats or around heavy bodies of coarse-grained granites. It is also a noteworthy fact in this area that the more irregular the intruded body of porphyry the more intensely the sediments in contact with it are apt to be altered. Thus the laccoliths of Alpine and Burnett creeks have baked and toughened the Cambrian shales considerably, causing them to assume a slaty character, but the limestones above these slates are almost unaltered; while at Black Butte, on the other hand, the whole mass of upturned sediments has suffered a very great degree of alteration, and around the Cone Butte mountain mass the limestones and shales of the Jurassic beds are converted, on the back of the irregular laccolith, to marbles and slates of the most metamorphic character, and even the Cretaceous sandstones are changed to quartzites. It seems probable that this is due in part to the considerable thickness of Cambrian shales over the large laccoliths (over 500 feet in the Alpine), which took up the effects of metamorphism and prevented the other beds from being affected. The shaly, penetrable nature of these Cambrian beds would allow the heat and moisture to spread out among them, producing, instead of a small, intensely altered zone, a metamorphism of a more gentle character through greater thicknesses. At a distance of a few hundred feet, and usually much less, all perceptible traces of metamorphic action disappear.

ORIGIN AND CAUSE OF LACCOLITHS.

What the origin of the upward, ascensive force in the molten magmas which gives rise to laccolithic intrusions really is we have, as Professor Dana so well expressed it, "many theories, but no real knowledge." We may, therefore, dismiss this phase of the subject, well assured that whatever may be its origin there is no doubt about the force itself, and that there is plenty of it to accomplish any work which the physics involved may demand.

It appears to the author that in the treatment of the mechanism giving rise to laccoliths the fact that it is really a vast hydrostatic press, while underlying the discussion of the subject by various authorities, has not been made as prominent as it might be. Suppose a fissure extending upward through comparatively undisturbed strata and forming a dike, and that it does not reach the surface. At some horizon where the conditions are right, the beds being easily separable at that point, it enters the strata as an intrusive sheet. As soon, however, as it spreads out, the whole upward-propelling force becomes as much greater as the horizontal area of the sheet is greater than the area of the dike or source of supply. It is in fact now converted into the upward member of a hydrostatic press. One thing, however, must be taken into account at this point, and that is, that owing to its viscosity lava is not a perfect liquid, and therefore does not transmit the pressure as a theoretical liquid would. A certain portion of the force must be expended in overcoming this internal vicosity, and the amount so expended would vary with the greater or less viscosity of the lava. The loss of force in this way would, however, tend to maintain the heat of the liquid. A certain amount of the force is also expended in overcoming gravity and raising the weight of the lava itself. Whatever remains over above these two is used in lifting the sediments, and may be said to roughly measure the effectiveness of the hydrostatic press.

As the sediments lift they tend to split, and into this split the lava tends to insinuate itself, and in proportion as it does so it becomes a part of the press and the lifting goes on. Thus a very liquid lava tends to spread itself widely for two reasons: First, because it transmits the pressure readily; and, second, because it readily enters all the cracks in the strata. It is, in other words, a wedge with a very sharp edge, which, with a stroke of given force, enters farther into the grain than one with a dull edge.

In proportion as the viscosity of the lava increases, these effects cease. As the distance from the point of application of the force increases, the retarding effect of the gradually cumulative viscosity comes into play and the onward-propelling force decreases, while the more viscous material, like a blunt wedge, splits the strata less and less easily. In this case, then, the upward effects of the force are felt much more strongly in the neighborhood of the point of application—that is, the point of supply—the sediments yield more and more, the material is locally concentrated, and a laccolith is formed.

The following factors, therefore, must be taken into account in discussing laccoliths: The upward force of the lava, which is transmitted in all directions, owing to its fluidity; the viscosity of the lava, which tends to diminish this force; gravity, which also detracts; the load of sediments; and the cohesion of the strata or their resistance to splitting. While we understand these factors in principle, we can not state all of them quantitatively, and hence quantitative discussions of laccoliths can not have any real value.

The consideration of these principles leads to several interesting applications of them.

Gilbert,[1] in his discussion of the Henry Mountain laccoliths, calls attention to the plasticity of strata when acted upon in large masses, and this has since been shown repeatedly in many ways. Therefore, if in any such intrusion it happened that the rapidity of the supply, or, in other words, the upward force, was so great that a laccolithic dome was formed, in the readjustment that would follow the final convexity of the mass would be determined according to the principles stated above. Hence a laccolith forming with comparative rapidity may afterwards readjust itself and assume a more sheet-like character. Such a process is probably of rare occurrence, but it is of interest to note that the convexity of a laccolith is not a necessary function of its depth but of the viscosity of the lava in relation to the other factors; hence laccoliths of various shapes and sizes may be found in the same horizon. We have seen this, from the present work, as occurring in the Judith Mountains.

It also seems evident that the rate of supply, or the time within which the force acts, must have a bearing in this case, and it is imaginable that the upward propulsion of the magma might be so rapid that a small laccolith could be formed where the arch of the strata was such that it was within the limits of plasticity and would tend to maintain itself after the upward force ceased, even though the magma was in an extremely liquid state.

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[1] Geology of the Henry Mountains, p. 97.

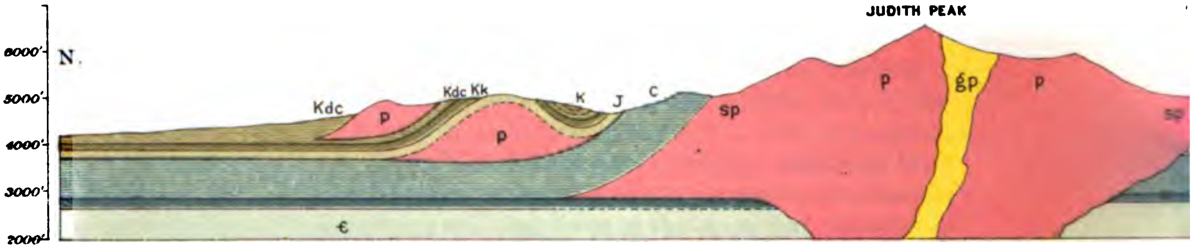
Also, there is with a given source of supply and a given viscosity a certain limit beyond which a lava can not form a sheet, but, if the supply of material continues, must form a laccolith. For at a certain radial distance from the supply the internal viscosity, assuming even that its ratio remains the same, will check the transmission of pressure and the onward-propelling, splitting force of the lava; but, the supply continuing, the strata must uparch and form a laccolith.

Another point of interest is that clearly the mechanism of the laccolith is complete without regard to the chemical composition of the lava or its specific gravity; these have no direct or controlling influence on its formation. But while they may exert no primary influence, secondarily they are of considerable moment, and in this way: Very acid magmas have no determinate point of solidification; like melted glass, they stiffen more and more gradually until rigid, and this rigidity is itself largely a function of mass. This we see in the extrusive material, and undoubtedly the same capacity for high degrees of viscosity, though not carried to the same extent, exists when such magmas are intruded. The basic lavas, on the other hand, preserve, comparatively, a high degree of liquidity down to rather low temperatures, with a quick process of solidification by rapid crystallization. This is well illustrated in blast-furnace slags, where the constant endeavor is to keep them as near as possible to an orthosilicate, such as olivine, in composition, while an increase in silica means an increase in viscosity and in the heat necessary to keep the slag fluid. Examples of a similar kind are familiar to all petrographic geologists.

The result is that the basic lavas will tend in the main to form sheets and not laccoliths, and that while, the conditions being right, laccoliths may be expected for lavas of any composition, and will undoubtedly be found composed of very basic rocks, yet, for the reason given above, it is certain that they will generally be composed of acid rocks, since these will more often possess the necessary viscosity.

From what is stated it is clear that there is no difference in principle between an intrusive sheet and a laccolith except the degree of a certain kind of form; a laccolith is a short, thick sheet, or a sheet is a thin, flat laccolith, as one is disposed to regard it. Those, therefore, who, never having seen them, confidently pronounce laccoliths to be mechanically impossible, must at the same time deny the existence of intruded sheets.

In areas of thick, easily separable strata, undisturbed by foldings or displacements due to tectonic forces, in which igneous intrusions have taken place, laccoliths, like sheets, are perfectly normal methods for the occurrence of igneous rocks, and, from a consideration of the factors involved their existence, could have been predicted from



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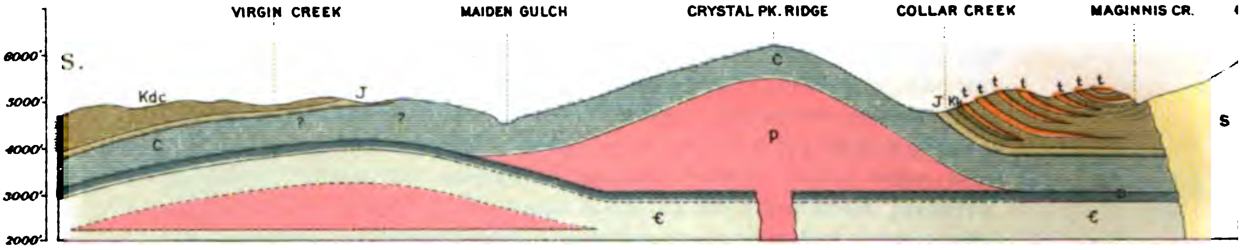

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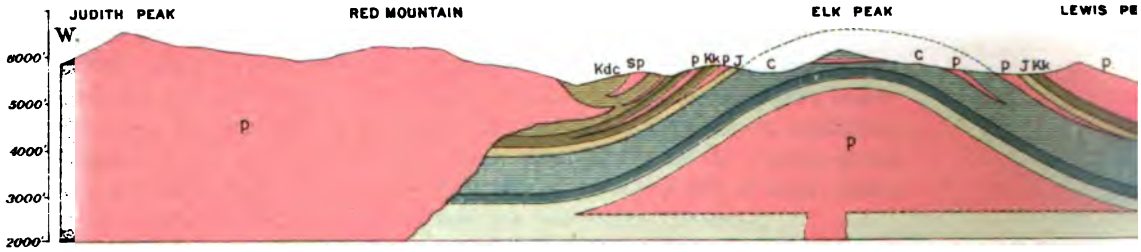

SECTI

CRETACEOUS		JURASSIC	CARBONIFEROUS	SILURIAN AND DEVONIAN	CAM
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BENTON FORMATION Black shales & sandstones DAKOTA FORMATION Red clays & sandstones.	KOOTANIE FORMATION Shales sandstones & coal.	Shales thinly bedded limestones and sandstones.	Massive bedded limestones.	Thinly bedded limestones.	Conglome shales a bedded l

GEOLOGIC SECTION

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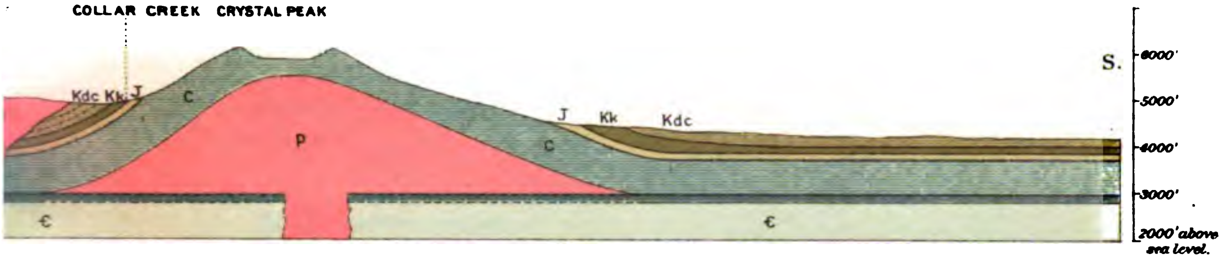
Walter Harvey Weed Geologist in charge.
Geology by Louis V. Pirsson.



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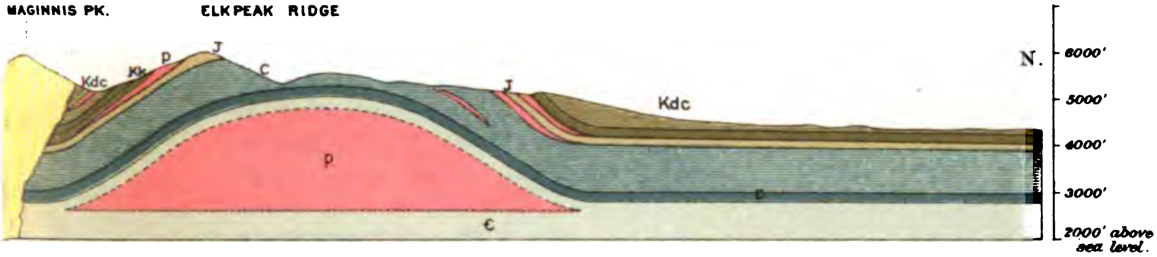

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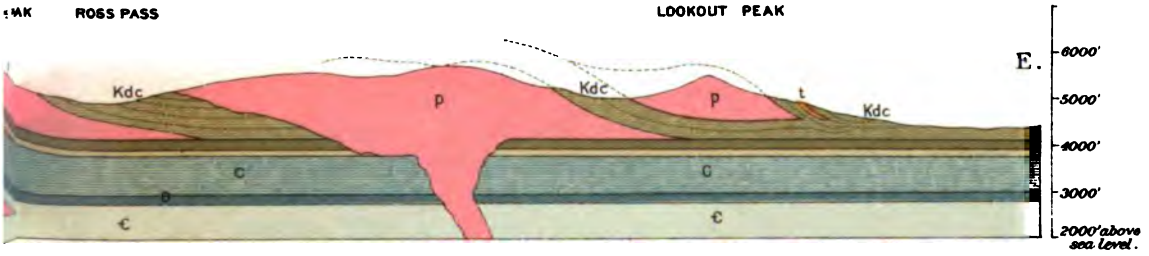

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IGNEOUS ROCKS

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S, JUDITH MOUNTAINS

ale

2 3 MILES.

JULIUS BIEN & CO LITH. N.Y.

mechanical laws if examples of them had never been discovered. The necessary conditions are so largely present over such great areas of western North America that they here constitute one of the commonest types of intrusion, and may be seen and studied under every imaginable condition of environment, stage of dissection, and variety of form.

THE INTRUSIVE STOCKS.

If the molten magma is forced upward with sufficient rapidity it is evident that the proper adjustment of load necessary to form a laccolith can not take place; and as the magma ascends from one horizon to another it continually spreads out laterally as the lateral resistance diminishes, rupturing and tearing up the beds and carrying this material on with it. Eventually it may in this manner reach the surface, giving rise, perhaps, to volcanic phenomena or causing effusions of igneous material. On the other hand, after a certain height has been reached in the strata, the diminishing of the lateral resistance of the beds, due to the lighter load above them, may permit the magmas to seek relief by lateral expansion, and in so doing they may lift the lighter beds above them and solidify beneath them; thus from above they would simulate a laccolith, but would differ in having no proper floor. So in the sections, Pls. LXXXII and LXXXIII, Judith Peak is represented as being of this character, as is also Maginnis Peak, while the Cone Butte mass (shown in section F-F, Pl. LXXXIII, to the right) would indicate a transition from the laccolith to this type. It is possible that this is Russell's idea of a volcanic plug doming up the strata. Such stocks or intrusions would then be represented by fan-like expansions from below.

SUMMARY.

It is shown in this chapter that the Judith Mountains are composed of six principal laccoliths, five of which are below the Paleozoic and one above, with numbers of smaller ones which grade eventually into sheets. This gradation is discussed, and it is pointed out that the distinction between the laccolith and intrusive sheet is an arbitrary one. The forms of the laccoliths are treated of, and it is shown that some are asymmetric, but still may be called laccoliths. The jointing in the sheets and laccoliths is shown to depend more on the chemical composition than on the shape and size of the mass. The contact metamorphism is shown to be usually small. In the discussion of the cause and origin of laccoliths the controlling factors are shown to be the viscosity of the magma, the rate of injection, and the load of sediments and their plasticity, when in mass, under stresses. Finally it is shown that intrusive stocks may show fan-like sections and dome up the strata.

CHAPTER VII.

By W. H. WEED and L. V. PIRSSON.

MINERAL RESOURCES.

HISTORY OF DEVELOPMENT.

The Judith Mountains present peculiarly favorable conditions for a study of the relations of ore deposits to geologic structure. The problem is a complete one, as the geographic isolation of the mountain group corresponds to a geologic isolation as well. The region presents a novel kind of ore deposits, occurring in connection with laccolithic and other igneous intrusions which have disturbed previously horizontal rocks. The mountain-folding and profound dynamic movements which occurred in the Rocky Mountain region have not taken place here. The mine workings are as yet, unfortunately, not extensive enough or deep enough to afford data for an exhaustive or detailed study of these interesting ore deposits.

Very little can be written concerning the history of the mining development of the Judith Mountains. In the early settlement of the State the mountain groups of the plains were not regarded as favorable prospecting grounds by mining men. Prospectors discovered rich placer gravels in the region about the year 1880, and soon after locations were made of both gold and silver properties.

The first workings appear to have been those of the Collar mine. A 10-stamp mill and hoisting machinery were erected, but they were soon abandoned, and were afterwards removed to the Spotted Horse mine. In 1881 the Maginnis Mining Company was incorporated, and purchased the Montana and Oro Cache lode, and a year or two thereafter erected a 10-stamp mill upon the property, which was worked with more or less success for several years.

In the spring of 1886 Mr. P. W. McAdow acquired control of the Spotted Horse mine. After spending $1,000 in driving a tunnel the ore was found, and after that the ore paid all expenses of mining and furnished a profit besides, being very rich and easily handled. Mr. McAdow states[1] that not less than one million and a half dollars of gold bullion has been taken out. It is locally stated that at times the rich bodies of soft, decomposed telluride of gold were taken out with a spoon and packed in small sacks by the owner.

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[1] In a MS. letter dated April 21, 1897.

The discovery of the pocket of silver-lead ore of the Cave mine led to the erection of a small smelter below the town of Maiden, but this was abandoned after a brief existence, when the ore was exhausted.

The picturesque intermontane town of Maiden soon sprang up as the outgrowth of the development and working of the Maginnis and Spotted Horse mines. At the height of its prosperity, in 1888, it had a population or about 1,200 inhabitants, and was well supplied with stores of various kinds, and a few buildings of stone were erected, with many frame and log dwellings. In the summer of 1896 the town contained fewer than 200 inhabitants.

Fort Maginnis, a former military post, has been abandoned for several years, and though maintained as a post-office, has less than a dozen residents.

The town of Giltedge is the direct outgrowth of the development of the mines from which it is named, and is largely dependent upon the mines for its existence. It has about 150 inhabitants and is situated in the level, open country south of the Giltedge mill.

Although the district is suffering from the blight which has at times overtaken the best of mining districts, the future looks promising, and enough has been seen of the ore deposits to warrant the prediction of prosperous times for the mining industries of the Judith Mountains when financial and economic conditions are more favorable.

THE ORE DEPOSITS.

CHARACTER OF THE ORES.

The Judith Mountain ores are mainly those of gold. A little argentiferous lead has been found, and the gold contains some silver alloyed with it; but silver is of minor importance in this district from an economic standpoint. The ores consist of country rock impregnated with and replaced by quartz and fluorite as the most abundant minerals. They are all from the zone of leached and oxidized rocks.

The ores greatly resemble in character those of Cripple Creek, Colorado, of Mercur, Utah, and of the Little Rocky Mountains of Montana. Like those of the localities mentioned, they do not occur in veins or in well-defined shoots, as is so commonly the case with gold ores. The occurrence of the richer bodies in the limestones near the porphyry contact is unique for gold ores. The characteristic ore of the district is a more or less decomposed and crushed limestone, containing angular masses of brilliant purple fluorite and quartz intimately mixed. Another type, that of Giltedge, has no fluorite or other prominent gangue mineral of any kind, appearing to be merely an altered, crushed, and brecciated clayey limestone. Detailed description of the types of ores from the more important mines is given with the accounts of the mines (pp. 599–613).

Of course a gold ore, as a rule, shows little of the metal to the naked eye, but, generally speaking, it has a definite character by which it is recognized when mined and by which it may be described. It may be, for instance, a mixture of quartz with pyrite or a rusty gossan resulting from the decomposition of the same, but in the present case it would be impossible to give any definite description which would cover the character of the gold ores in these occurrences. Sometimes it is a rusty limonitic limestone, sometimes a dark brownish-gray to clear-gray limestone, rather crystalline, but otherwise not appearing altered, and showing here and there patches of red-purple fluorite with dull, greenish, soft, earthy flecks, which sometimes have a bronze-like color and which are an altered gold compound, probably a telluride. These spots, on treatment with intense heat and a flux, develop into beads of gold, and a specimen of the limestone, which has a dull, faint greenish tone, but otherwise shows no hint of the precious metal, will, on heating in a forge ("blistering"), come out spangled and glittering with beads and threads of gold. This is the character of the best and richest ore which has yet been found in the district, and the bonanza shoots of the Spotted Horse were composed of it.

Again the ore may be a silicified limestone with mixtures of quartz and occasional stains of copper by weathering, or it may be a hard, black, cherty material in which are fine points, appearing like pyrite, with an occasional minute, microscopic fleck of free gold. This is the only unoxidized and unaltered material which has been seen anywhere in this class of ore deposits, and such cherty masses are generally surrounded by decomposed limestone and limonitic material.

The limestones are usually much cracked, and these cracks are frequently filled with decomposed limonite material. The ore ordinarily occurs in thin seams, stringers, shoots, and cavities, as it generally does when deposited in limestone.

In the midst of so much alteration, and from the lack of any definite wall, it appears difficult to tell ore-bearing material from that which is barren except by assay checks, but the miner experienced in the Gold Hill workings says that the ore has nearly always a "lively, firm, clinky" feeling, which practically means that those portions are the richest in ore which have the most secondary silica, are the most cherty in character, and feel rough and sharp to the touch, or grind under the heel with a crushing, clinking sound. The reason for this appears to lie in the fact that as the ore was deposited from solutions, silica of a secondary nature was also deposited with much of it at the same time, and thus the most siliceous, flinty portions are apt to be the best ore.

In some places the ore appears of a more limonitic character, as at Giltedge and in the New Years mine, and even pure limonite bands in the limestones not directly connected with any porphyry intrusion may contain gold, as at the Black Diamond claim, on the east side of the Crystal Peak dome, where the ore runs as high as $14 a ton.

Free gold occurs in all the ores thus far worked. The gold appears to be most abundant in the quartz-fluorite masses. In the richest ores it occurs in particles or small cuboidal masses, generally platy and open textured, or spongy, rarely one thirty-second of an inch thick and one-eighth of an inch across. The gold is always dark colored, being coated by a rusty or yellowish-brown film. Tellurides occur with the free gold, and the condition and form of the gold indicate its derivation from such tellurides by oxidation. The tellurides thus far observed are too finely disseminated to afford satisfactory material for testing. The color and luster are not those characteristic of calaverite. Unaltered pyrite occurs somewhat rarely with the gold ores, and under the microscope it seems to contain small particles of what is possibly a telluride.

Silver minerals occur in small quantities in the ores of some of the undeveloped prospects, and quartz stained with silver sulphides was found on the dump heap of the old Collar mine. Assays show the presence of a considerable proportion of silver in the gold ores, and it seems probable that in this case the silver was derived from a gold-silver telluride. The only considerable quantity of silver ore mined came from the Florence mine.

Lead ores occur but sparingly in the district, and most of the silver-bearing lead ore was found in limestone at the Cave mine. Galena occurs sparingly in several of the ore bodies of various prospects, but never in large enough quantity to have economic importance.

Copper minerals are extremely rare in the districts, their only occurrence in any quantity being at the Northern Pacific claim, where chalcopyrite was observed.

Fluorite is the common and characteristic mineral of the best ores yet worked. It is generally conspicuous by reason of its brilliant purple color, which has faded to pink on those ores which have been long exposed to the weather. It occurs chiefly in a finely crystalline condition, intimately mixed with quartz and forming small angular blocks in the limestone of the ore body, but is sometimes found, lining vugs, in the usual cubic crystals. Its significance will be alluded to later in describing the ores.

Quartz, though less prominent than the fluorite, is of even wider distribution, filling the interstices between the fragments of broken limestone and impregnating the contact zone generally. Siliceous material which is apparently not quartz is often found, especially at Giltedge, where it forms a jaspilite substance with conchoidal fracture and brownish color, occurring in bowlders in the soft, earthy material.

Calcite is abundant, but in most cases is of secondary origin, and must be attributed to the alteration of the ore deposit itself. In the decomposed porphyry calcite replaces the ferromagnesian minerals, and here the calcite must be assigned to the period of ore deposition, as it contains minute particles and specks of pyrite.

Superficial alteration has taken place throughout the district, all the ores thus far mined having come from the zone of alteration. The original ore deposits have been decomposed and leached by oxidation and hydration of their original minerals, due to the access of surface waters and air. The depth of alteration is not known, as the deepest workings, those of the 400-foot level of the Spotted Horse mine, do not extend down to the unaltered ores. The gold is mostly free, but may be confidently expected to change to tellurides in depth. The alteration of the deposits has in most cases altered the iron minerals and pyrite to rusty masses of limonite, and at the same time the gold minerals have been oxidized and the gold has been set free. The feldspar of the eruptive rocks has been altered to sericite and sometimes replaced by calcite, and the porphyry in many places leached to a white siliceous or kaolin-like mass.

The value of the ores, like that of most gold ores, is quite variable, running from the rich bonanzas of the Spotted Horse mine, which went many thousand dollars to the ton, to the leaner ores of many prospects which would hardly pay for working. One may say, however, that the gold ores of the district are, in general, of low grade, not exceeding $10 to the ton.

MODE OF OCCURRENCE OF THE ORES.

The gold ores of the Judith Mountains occur in small quantities in placer gravels, but chiefly in deposits associated with the igneous rocks of the district. True fissure veins in the strict sense of the term do occur, but the more valuable deposits thus far worked are not of this nature. The geology of the region has been fully described in the foregoing pages. It has been shown that no true volcanoes existed here, but great masses of molten rock pushed up the level beds of limestone into great domes, beneath which the igneous rock cooled and solidified. At the same time molten rock was intruded between the arched beds of rock of the domes. Other bodies of igneous rock were forced violently up through the limestones and shales, but appear to have failed to reach the surface, though now exposed by denudation. Phonolite dikes were intruded in the hardened igneous rocks and the sedimentary beds alike in the northern part of the area. This is, in brief, the geology of the region now exposed by the gradual wearing down of the mountains by erosive agencies.

In connection with these igneous intrusions different types of ore deposits occur, which may be grouped as follows:

1. Ore deposits in fissures in the porphyry masses.
2. Ore deposits along contacts of phonolite dikes.
3. Ore deposits in the limestones at the contact of an irregularly intruded mass of igneous rock or beneath intruded sheets of porphyry.

The first and second classes are at present of relatively small economic importance. The dikes filling the fissures in porphyry show a fissuring of the rocks at or before the time of their injection, but it is certain that the fissures now holding mineral deposits were formed at the same time and are of the same character as those filled by dikes. At any rate the deposits occurring at the contact with these phonolite dikes may be due to the penetration of ore-bearing waters along the shrinkage cracks.

ORE DEPOSITS IN PORPHYRY.

These have played but a very subordinate rôle in this district up to the present date. In certain places the porphyry itself, from its cracked and fissured condition, seems to have been the way for ore-bearing solutions, and along such areas there are ore deposits. In a number of places, like the interior of Alpine Gulch, the porphyry has been prospected and free gold may be easily panned from the rich material filling very thin cracks. Such deposits are usually but paper-thin and of limited extent, and it is a question whether such limited deposits in the massive porphyry would pay for working. If they were found to increase in width and extent they of course would do so, but this can be told only by development work that has nowhere as yet been undertaken.

On Judith Peak and in the porphyry in the immediate neighborhood there occur several seams of quartz filled and colored with purple fluorite. The association is such that one might expect the presence of a gold ore similar to the ores of Cripple Creek, but the veins have so far yielded only the baser metals, mostly lead and copper.

ORE DEPOSITS ALONG CONTACTS OF DIKES.

In this class of deposits feldspar-porphyry or phonolite dikes, usually those cutting the shales near the contact, have been the locus of active prospecting. At times intruded sheets occur and indeed the more complicated the mixture of sheets, dikes, and slates the more they have been prospected. Usually in these occurrences the igneous rocks are greatly leached and altered, and it is difficult to tell the character of the ore, but in a few cases they are quite unchanged, and it is then seen that the porphyry appears somewhat silicified and is more or less filled with pyrites.

It is difficult in this class of deposits to always discover with certainty which of the various rocks of the mines is ore and which is gangue; usually the dike itself is regarded as the "vein" and is mined, but sometimes the wall rock is mined also, and both appear to be regarded as ore.

No considerable mines have as yet been developed in this class of deposits. The Hanson properties, at the head of East Armell Creek, have been most thoroughly tested, and the Golden Jack, Butcher Knife (the latter in limy Cambrian shales), and Golden Eagle are prospects which are being developed. The value of these ores is never claimed as being high, from $6 to $14 a ton, the average being about $10 a ton. There are many such claims, and there is no doubt that considerable bodies of low-grade ore of this character exist.

ORE DEPOSITS IN LIMESTONE NEAR CONTACT WITH IGNEOUS ROCKS.

This class of deposits is by far the most important and the most productive type in all of the mines which have been considerable producers of ore. The Spotted Horse, Maginnis, and Giltedge properties are of this description. The two former mines are located, as will be described, on the contact of the Gold Hill porphyry mass with the heavy Paleozoic limestones. The contact, as shown in fig. 54, p. 600, has a broken, irregular wall, with a general pitch toward the porphyry. If it were of a less irregular character the limestone would form the hanging wall, as, indeed, at times it does. In these mines the best and richest ore is not found directly at the contact, but a short distance beyond, in the shattered limestone. The Giltedge and New Years ore bodies differ from this only in occurring on the under contact of an inclined porphyry sheet intruded in the limestone.

The association of the gold and fluorite seems to be an intimate one. In a general way it may be said that the amount of gold present is found to increase with the proportion of fluorite. Thus the facts show that the highest-grade ores and richest ore bodies have been found in the Spotted Horse workings, the ores carrying the larger proportion of fluorite. The Maginnis ores carried less fluorite and less gold, when the general character of the ore is considered. The New Years, which shows fluorite masses, is a still lower grade ore, and the Giltedge properties, whose ores are of low grade, show none of the brilliantly purple fluorite noticeable in the ores of the mine previously mentioned, although colorless fluorite is sparingly seen.

SOURCE AND DEPOSITION OF THE ORES.

Owing to the fact that detailed examinations of the mine workings were not practicable, but little can be stated concerning the source of the ore other than may be deduced from surface observations. The descriptions already given have shown that the chief and thus far the only valuable ore deposits worked occur in the brecciated contact zone between intruded igneous rocks and limestones. These intrusions are either irregular and break up abruptly through the limestones, or they occur as sheets intruded between layers of them. Faults are found near the site of greatest mineralization, but it is believed that the brecciation of the limestone would of itself furnish an available channel for uprising mineral-bearing waters. Later movements undoubtedly occurred, however, as the brecciated ores show fragments of rhyolite-porphyry in limestone, and this proves brecciation after the cooling of the igneous intrusion. Differential shrinkage—that is, the shrinkage of the cooling igneous rock and the different shrinkage of the adjacent rock walls—would also tend to form favorable conditions for uprising mineral waters.

That the ores have not been derived from the body of igneous rock immediately at hand seems evident to one familiar with the decomposition of rocks by hot waters and vapors. That the eruptive rocks at greater depths furnish the gold seems, however, certain. In the other outlying mountain groups of the State no ore deposits occur in surface volcanic rocks, but where the igneous intrusions have been denuded ore deposits are found near the contact. As ores occur only under such conditions and no others in these mountains, it seems certain that ore deposition has been dependent upon the igneous intrusions.

The close association of the gold and fluorite is significant here, as it has proved to be at Cripple Creek.[1] The presence of fluorine vapors is a frequent characteristic of volcanic emanations, and its action upon the readily attackable limestone would result in the formation of fluorite. Phonolite-porphyry (tinguaite) often contains fluorides in the fresh and unaltered rocks. Such rocks were intruded after the solidification of the laccolith and other great intrusions, and the ore deposition, with fluorite formation, seems to have taken place at about this time. It is to be noted that where the large ore deposits occur there are no rocks of this nature. As already stated, however, small deposits of low-grade ore are also found in intimate connection with such rocks throughout the northern part of the area, in the Cone Butte district.

Microscopic examinations of thin sections of the purple ore show it to be an intimate mixture of quartz and fluorite. The descriptions given by Mr. Penrose of similar ores of Cripple Creek apply quite as well to those of the Judith Mountains.[2]

While the workings showing fluorite in greatest abundance have had the richest ores—and there seems to be a general relation between the abundance of fluorite and of gold—the number of occurrences is not sufficient to base definite conclusions upon. At Cripple Creek, Colorado, the association of the richest ores and most abundant fluorite is the exception and not the rule. Here, as there, it is true that in the same mine the purple ore "sometimes contains large amounts of gold, sometimes but little, and sometimes none." The Judith ores add another to the small but important list of telluride deposits where the ore is associated with fluorite.

The evidence of aqueous action is apparent in the decomposition and alteration of the porphyry adjoining the ore deposits and in the ore gangue itself. This process has not gone far enough to efface the brecciated character of the ore, or to produce the frothy silica seen at other localities, but it is nevertheless quite marked. The summit of Red Mountain also shows the extensive alteration of the larger porphyry mass.

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[1] R. A. F. Penrose, Geology and mining industries of the Cripple Creek district, Colorado; Mining geology of the district: Sixteenth Ann. Rept. U. S. Geol. Survey, Part II, 1895, p. 157.

[2] Loc. cit., p. 158.

The mode of ore deposition is probably a replacement of limestone. The fluorite masses occur in angular, sharply defined pieces, resembling in shape and size the fragments of limestone about them. In the richest ores the fluorite replacements carry the gold, and the surrounding limestone fragments are of low grade. It is difficult to understand why one fragment of the limestone should be entirely and completely replaced by fluorite and quartz, while other fragments near by are only flecked by small grains of it or carry none at all. It is easy to understand the replacement of limestone by fluorite in the waters carrying hydrofluoric acid, but the selective action of the solutions is not explainable by any phenomena seen in the specimens, although there seems to be a possible favoritism for the portions of the limestone carrying the most organic matter. The cavities now seen in the ore appear to be wholly secondary, and the ore filling was brought about by metasomatic replacement and not by the filling of open cavities.

Ore shoots or bonanzas occur in the ore bodies of this region, as in nearly all gold districts. The name is used in the generally accepted sense, as applying to a part of the ore body in which the gold is especially concentrated, and which is surrounded by ore of lower grade. In the Judith deposits these bonanzas are surrounded by lean ore, often too poor to pay for working, or in other cases by good average ore. In the workings seen by the writer, there was no general rule governing the occurrence of these bodies, but they seem to be grouped together. The ore shoots are supposed to extend a considerable distance downward with the vein, but in the Judith mines they do not form such extensive shoots, but rather what the miners often call "bowlders" of rich ore. No data were obtained tending to any special characteristics of these bowlders, and the records of the production of the two great mines are not available; in one case they have been destroyed. It has been noticed, however, that these "ore bowlders" do not occur in the shaly or impure limestone, but are found in the purer, coarsely crystalline limestone darkened by organic matter. As has been already stated, the ore deposit is not a fissure vein, but more in the nature of stockworks or mineralized masses of broken rock fragments (breccia) which have been more or less altered and replaced by ore.

An examination of the mines, so far as it was practicable, and of the minerals seen on the dump heaps, appears to show that the following processes have been at work: First, the eruption and injection of the porphyry, attended by more or less rupture of the limestone strata, with some direct alteration from the heated masses. Second, the secondary processes attending the cooling of the deeper-seated porphyry (pneumatolytic), in which heated waters circulated in the contact zone—waters which were of a more or less acid and solvent character from the gases given off by the cooling and crystallizing igneous magmas, especially fluorine vapors. These have acted on the limestones, and to some extent on the porphyry itself, with deposition of ore and the formation of other minerals, such as secondary silica, crystallized quartz, fluorite, pyrite, and perhaps others. Third, the alteration processes, caused by the oxidation and leaching action of surface waters charged to a greater or less degree with carbon dioxide, air, and acids formed by vegetable decay, producing decomposition of the limestone and porphyry, with deposition of limonite, formation of caverns and smaller cavities and the lining of them with calcite crystals, alteration of the ores, except where protected by being in chert, formation of clay, and similar chemical work.

As has been said, in the Judith Mountains the ores are gold ores, and although the alteration has been very complete to all depths which have yet been worked, it is pretty certain that the ores were originally tellurides.

It will be noticed that the occurrence of the ore bodies is quite similar to that of the great silver-lead deposits which have in recent years been actively developed in so many localities in the Rocky Mountain region. The ore bodies, therefore, have much of the character and all the uncertainty of occurrence that such classes of silver-lead deposits have. They occur in pockets, stringers, shoots, and chimneys, and the development work may lead to rich bonanzas or be prosecuted for great distances with little or no return. In general, however, it may be said that the work which has thus far been done tends to show that the zones of mineralization are quite extensive and probably reach greater depths than have yet been worked, and that skillful and intelligent development has usually been rewarded. Unfortunately too little of the latter has so far been shown in the district.

It has been generally noticed in the region, both in the cases mentioned and where prospecting has been combined with assay tests, that on contacts of limestone with porphyry the best results have been obtained where the contact plane is inclined or hades, with the porphyry as the hanging wall. Thus, in the case of intruded sheets of porphyry it is always the under contact that is worked or prospected, while the upper contacts have generally proved unremunerative. This might be attributed to the ore having been leached out of the porphyry by the circulating waters and having been deposited in the limestones below, while in the reverse case the waters passing through the upper limestones would not yet have been charged with ores. Although this appears at first glance a plausible theory, it is by no means a certain one. If the ascending mineralized waters came from great depths below and passed upward along an inclined contact plane, the ore would be mostly deposited in the limestone and not in the porphyry, because, being of acid nature, as we have shown above, they would be neutralized by the limestone, and the ores would be deposited in it. Thus, with the limestones as the floor for the ascending currents, the neutralization and deposition of ore would be more complete than in the reverse case.

Similar contacts of porphyry with Cambrian or Mesozoic shales have so far proved unremunerative, and no important mine has been developed in them. At the present time only one prospect of this class—the Butcher Knife, in Alpine Gulch—is being developed, the results of which time alone can tell. It might be surmised that these shale beds have not proved ore carriers to so great an extent as the limestones on account of the difference in their chemical composition, which has been less favorable for action on the ascending acid currents. In a few cases ore deposits have occurred in the limestones which are not directly connected with any body of porphyry, but since all of the limestones in this district which are exposed have been uplifted by masses of porphyry from below, it is clear that solutions carrying ore might circulate through these rocks at considerable distances from the porphyry. In such cases it is always a silver oer that occurs, and examples are found in the Pilgrim claim, on Crystal Peak; in the Last Chance,'in Elk Peak; in the Wocasek claim, below Maiden; and in the Cave mine, in West Armell Creek. Though some very small bodies of rich ore have been found in these deposits, nothing warranting extensive development has yet appeared.

The district is in fact essentially a "gold camp," and while silver ores, both of the sulphuret variety and also associated with lead, occur, as well as gold and silver ores together, there has so far been only one mine developed which has produced silver and paid well—the Florence, on Crystal Peak.

FUTURE OF THE DISTRICT.

The future development of the mining resources of this region must in a great measure depend upon the securing of cheap transportation and the inducements offered to outside capital. At present the remoteness of the region from the railway, which is over 100 miles distant, is a great drawback. It is thus little visited and rarely heard of, for its isolation not only hinders its accessibility to a market, producing extremely high freights, but causes it to attract little outside attention.

It is a fact to be noted that in nearly all of the prospects which have so far been tried, ore—usually gold—has been found, though not always by any means in notable or paying quantity; or one might say that in the great majority of cases where the altered porphyry and its under contact of limestone have been assayed more or less gold has been shown. It is therefore certain that gold has a very wide distribution in the district, being found in the main masses of porphyry, in their contacts, and in the dikes and sheets. It appears therefore safe and reasonable to say that there are considerable bodies of low-grade gold ore present in this district which have not been developed.

The contact zone of the Gold Hill porphyry, between the Spotted Horse and Maginnis mines, should prove a favorable development ground. Under proper conditions several small mines, conservatively managed and intelligently conducted, may find profitable returns in this district, even though the chance of finding bonanza ore bodies like those in the Spotted Horse may never be realized.

If the future shows a considerable mining development in this region, the scarcity of water may be much felt, while that of timber will inevitably become a serious problem.

DESCRIPTIONS OF MINING PROPERTIES.

MAGINNIS MINE.

This mine was located in the earlier period of the camp, and in 1881 passed into the hands of a corporation known as the Maginnis Mining Company, which purchased the property known as the Montana and Oro Cache Quartz Lode and a year or two thereafter erected a 10-stamp mill. An investment of several hundred thousand dollars was made in the mill and power plant and in obtaining a water supply, for which a 6 by 6 inch flume several miles long was constructed. The mine was worked from 1881 to 1894 under several superintendents, but the returns to the company were unsatisfactory and the mine was closed down. From 40 to 50 men were employed in the mine and mill. The ore is considered free milling, though it is stated that not more than 65 to 70 per cent of the assay value was saved. The cyanide process, so far as is known, has never been tried on this ore, though some of the tailings have been treated in this way with indifferent success. The mine is located at the very head of Warm Spring Creek, at the upper end of the town of Maiden and just under the divide to Maiden Gulch. A view of it is given in the accompanying plate (Pl. LXXXIV). At this point the porphyry mass of Gold Hill comes in contact with the infold of strata lying between the Alpine and Crystal Peak laccolithic dome, as described elsewhere in this work, and the porphyry abuts against the Carboniferous limestone, a mass of the ledge belonging to the top of the Carboniferous series lying still uneroded on the divide and being seen from below as a prominent block-like crag against the sky line, as seen in Pl. LXXXIV. An examination of the mine workings shows that the ore is the characteristic one of the Gold Hill contact zone as found here and in the Spotted Horse mine.

The ore body of the Maginnis mine consists largely of a crushed and brecciated limestone, recemented and hardened by silica (quartz) and showing crystals and masses of quartz and calcite. Fluorite occurs somewhat less abundantly. The ore resembles that of the Spotted Horse mine. It shows both light and dark crystalline limestone and compact brown, bluish, or gray shaly limestone. A microscopic examination of a thin section of the characteristic purple ore, the richer ore of the mine, shows it to be composed of grains of quartz intimately mixed with almost colorless fluorite, the grains being of about equal size and the fluorite predominating. Scattered areas of a yellowish substance are seen that give an aggregate polarization and appear to be the result of the decomposition of some former iron-bearing minerals. This substance contains considerable iron hydroxide, but is not definitely determinable.

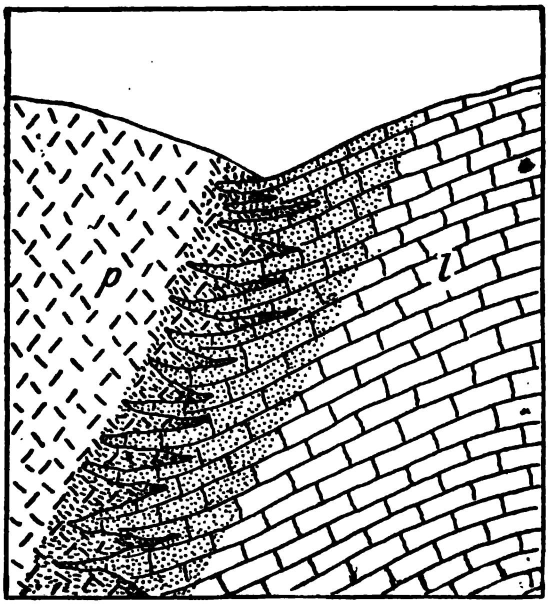
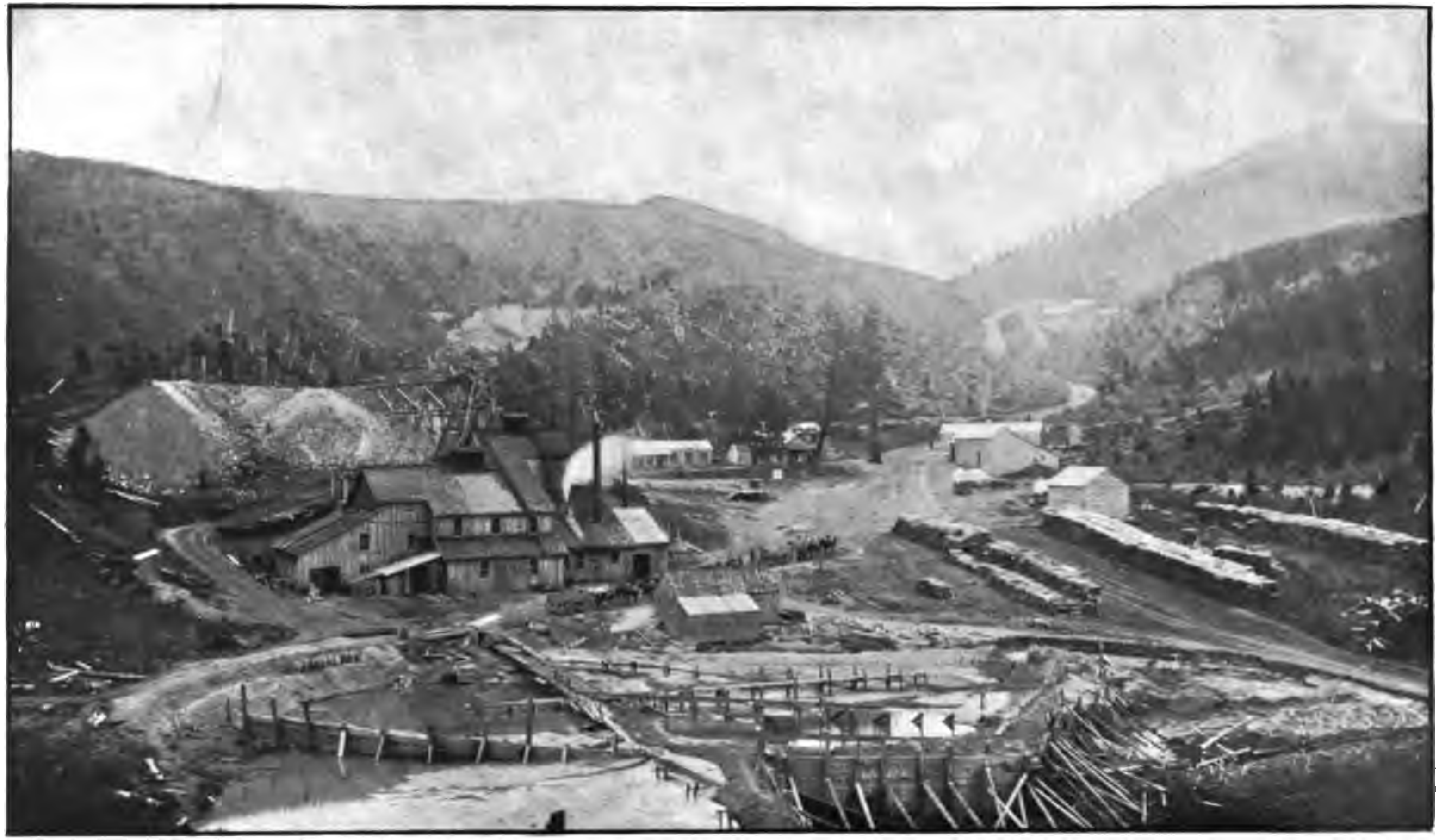


FIG. 54.—Diagrammatic section showing contact of porphry and limestone and zone of ore deposition. p=porphyry, l=limestone.

A winze has been sunk below the lower level, but sufficient depth has not been attained to reach below the zone of alteration. At times the contact shows slaty beds which are really altered shaly rock. The adjoining diagram (fig. 54) shows the general character of the contact area, the darkened portion being the ore-bearing zone. In the shaly beds very little good ore is seen, the best always occurring in the pure crystalline limestone. Of the best ore, the green and purple variety described above, a rough estimate by one familiar with the mine places the total amount mined at 500 tons. It is impossible to obtain a general average of the value of the ore; some has run at $50 to the ton, some very much higher, while much of it would average perhaps $20 to the ton. The mine is situated on the contact of limestone and porphyry. It has two levels, the lower, near the mill, being about 1,000 feet long, with a large number of side tunnels, stopes, and winzes; the upper, on the hill above, is about 300 feet long, and considerable work has also been done here. These workings show that the contact does not even approach a smooth wall, but is very broken and irregular, the porphyry having torn up and penetrated the beds of limestone in wedge-like masses. In general terms the whole plane



MAGINNIS MINE.

of contact hades strongly downward toward the porphyry. Thus in the various levels and stopes, while the chief working has been in a mineralized zone in the limestone, the workings frequently pass through porphyry, which appears now on one side and now on the other.

The amount of alteration suffered by the various rocks composing the contact has been very great; the limestones are generally decayed, cavernous, and filled with masses of limonite. In other places soft masses of limonite, or even of soapy, talc-like clay, are passed through. It is difficult, in the midst of so much alteration, to trace out the various changes which the limestones have suffered—first from the action of the intruded porphyry, second from the processes of mineralization, and lastly from oxidation and decay. The amount of the latter has been very considerable, and has been caused largely by the action of running water, as is shown by the caverns and old water pipes which fill the limestone. In one tunnel a natural pothole-like shaft was encountered, which showed no bottom at 150 feet of depth. Many of the caverns are coated with fine calcite crystals, and vary from vugs but a few inches in diameter to rooms of considerable size.

Above, near the divide, is the other property, called the South Shaft, 150 feet deep, with several levels. This gave a silver-lead ore, running, so it is said, some 60 ounces in silver, of which about 1,500 tons were shipped to Wickes. The buildings of this mine are seen in Pl. LXXXIV, on the road crossing the divide.

These mines, being rather high above the adjacent drainage channels, are very dry, and the old waterways found in working afford a steady draft of natural origin through them. At present, from nonusage, the mines and machinery are not in the best condition.

Pl. LXXXIV shows the Maginnis mill and tailings pond, with the dump heap of the lower level behind the mill. The mouth of the upper tunnel is seen in the background on the slopes of Gold Hill. To the right the road to the Spotted Horse mine, Giltedge, and Lewistown is seen going up the gulch and crossing the divide between Gold Hill and Sheep Mountain. The south shaft of the Maginnis mine is seen to the right of the road on the divide.

P. K. MINE.

Besides the properties already mentioned, the Maginnis Mining Company operates the Black Bull, Globe, and P. K. claims, the latter a mine situated on the mountain ridge that forms the Alpine divide at the head of Virgin Creek, and a short distance south of Pekay Peak. It is about 1,000 feet above Maiden and 2 miles distant by road. The development here consists of a tunnel 400 feet long, with a 200-foot branch, a lower shaft of 80 feet depth, and an upper shaft of 45. The ore was carried down by teams. The mine is situated on the contact of the Carboniferous limestone with one of the upper, intruded, lenticular sheets in the Alpine dome. The ore was considered a free-milling gold ore, and its character shows that the lode is likely to yield favorable results if careful, systematic exploitation is conducted for rich ore bodies.

SPOTTED HORSE MINE.

The Spotted Horse mine has been the great gold producer of the region and is one of the noted gold mines of the State. It is situated on the slopes of Gold Hill, a mile and a half from Maiden, near the ravine cut by a branch of Maiden Creek. (See Pl. LXXXV and fig. 47.) The mine was located in 1881 by Messrs. Anderson and Jones, who sold it to Messrs. P. W. McAdow and B. Dexter. Mr. McAdow became sole owner in 1883, and worked the mine very successfully for five or six years and then bonded it to the so-called Jay Gould Mining Company, composed of Helena people, for $500,000. The mine was worked by these parties for a year or two without much success and they then relinquished the bond. Mr. McAdow again worked the mine very successfully for several years, and finally sold it, in the winter of 1893, to the Double Eagle Gold Mining Company, composed of Chicago people. They worked the mine a year and a half, were not successful, and it fell to the lien holders, by whom it was sold to the present owners.

The ore body occurs at or near the contact of massively bedded white limestones with the intrusive mass of Gold Hill porphyry. The surface outcroppings of these rocks are shown in the sketch map (fig. 47) given with the detailed description of the geology of this place. The ore occurs wholly in the limestones, for although the porphyry is mineralized, it is of too low grade to work, and is generally base. The ore body consists of a breccia, or mass of fragments of broken rock, chiefly limestone, but carrying porphyry fragments as well, near the contact. The limestones were altered by the intrusion of the porphyry mass, being rendered more crystalline, as is so commonly the case, in the contact zone about intruded bosses of igneous rock, but few contact minerals have been observed. The processes of ore deposition and late surface alteration have changed the character of much of the rock and formed the clayey and shaly masses met with in mining.

The Cambrian rocks occur on both sides of the gulch adjacent to the mine, but in the workings they are not encountered. There is reason to believe that here, as elsewhere in this region, they would prove poor ore carriers. These rocks are faulted against the massive white Carboniferous limestones.

The ore body is extremely irregular. It appears to be similar to that of the Maginnis mine; that is, it occurs apparently where the porphyry projects into the limestone in jagged masses, and the contact has been brecciated, and the diagram given with the description of the Maginnis mine also illustrates the mode of occurrence of the ore body here.

Fig. 54*a* shows the workings of the mine as surveyed in 1889, the later workings having been sketched in. This shows the extreme irregularity of the workings and the unequal distribution of the ore. In every case where the levels have been driven into the ground immediately between the two shafts, rich ore bodies have been found, but this has been done only after drifting through barren ground. No systematic prospecting of the property has been done, although it would appear to offer extremely favorable conditions for diamond-drill work.

A cross section of the workings, so far as developed in 1889, is shown in fig. 54*b*. Later surveys have not been obtainable.

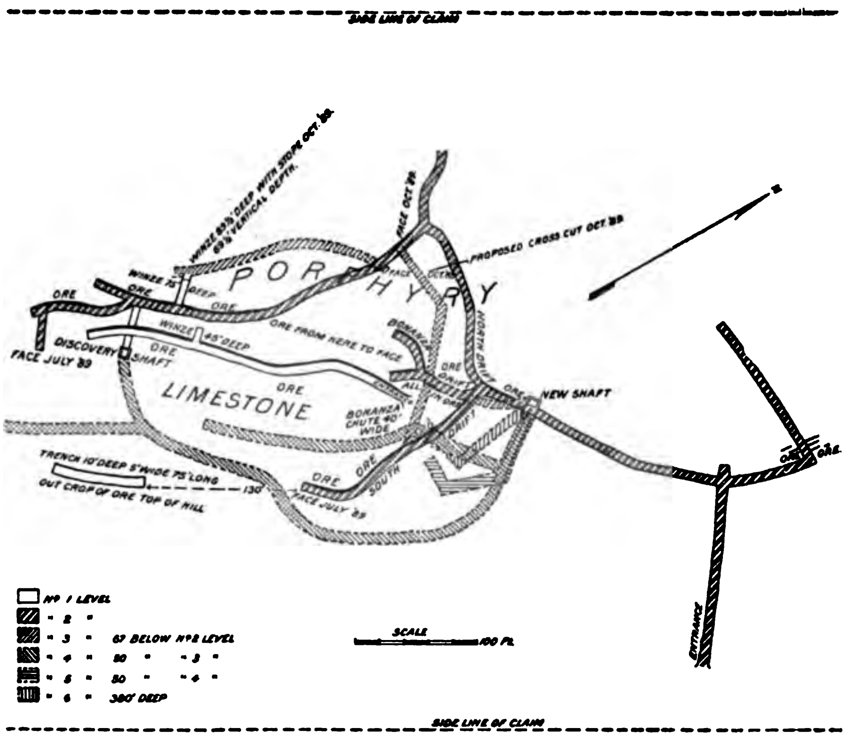


FIG. 54*a*.—Ground plan of workings of Spotted Horse mine, October, 1889, from survey by G. T. Wickes; fourth, fifth, and sixth levels of later workings sketched in.

Pl. LXXXV shows the hoist, mill, and general aspect of the surrounding slopes. On the extreme left of the view the Carboniferous limestones form a hummock on the hillside, and in this a bonanza of rich ore was found in 1893, which yielded $30,000, the body of rich ore being less than 10 by 25 feet across, and perhaps 15 feet deep. In the plate the distinction between the porphyry mass of Gold Hill, seen in the background, and the limestones of the mine, upon which the buildings all stand, is not very apparent, as no prominent outcrops occur. The distinction is more apparent near the mouth of Spotted Horse Gulch, where the limestones form the heavy outcrops seen in Pl. LXXIX, p. 528.

The Spotted Horse ores vary greatly in appearance, though the same general characters prevail throughout. The richest ores consist of coarsely crystalline, light-gray limestone, carrying fragmental masses of fluorite impregnated with gold. Other ores are of limestone of varying grain crossed by fractures or seams of earthy material, with parallel arrangement. The fluorite occurs both as angular masses replacing limestone fragments and in specks and particles in the compact limestones. The limestone is seen to be such, and not vein calcite, by its structure and by the calcite grains replacing fossils. The ores often show considerable secondary alteration and solution, forming open cavities lined with secondary calcite crystals. Bowlders occurring in the soft, clayey parts of the deposit show a center of cemented limestone, fluorite, and porphyry fragments, surrounded by concentric rings of soft, earthy brown material. The fluorite occurring as replacement of angular limestone fragments shows a contact film of brown ferruginous oxide, which may represent impurities of the original limestone, expelled during replacement. The coloring of the fluorite seems deepest where the limestone carries most organic matter. The shaft sunk upon the adjoining claim, the Kentucky Favorite, develops mineralized porphyry, which is of too low grade to work, though containing unaltered specks of telluride. The rock shows considerable pyrite and is quite thoroughly altered. Under the microscope this low-grade ore is seen to be a rhyolite (quartz)-porphyry of the type described in the chapter on the igneous rocks, but it has been greatly altered and changed by various agencies. It consisted originally of crystals of feldspar of small size, and occasional rare ones of quartz, embedded in a very dense, compact groundmass

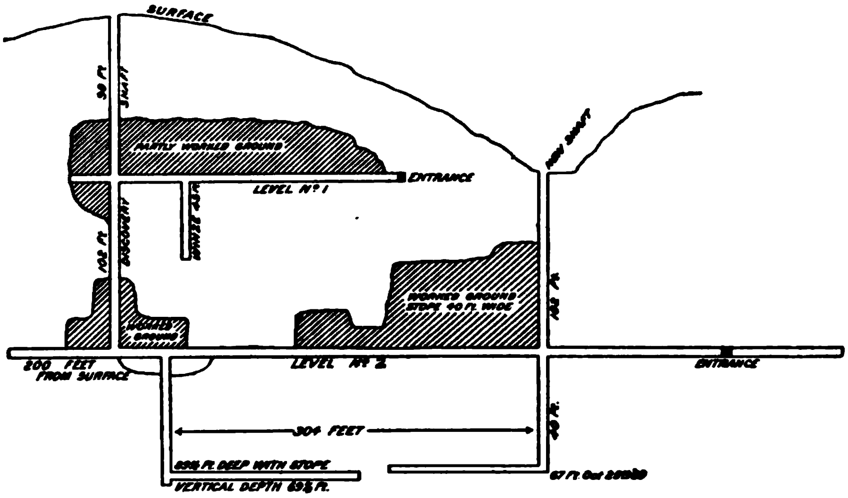
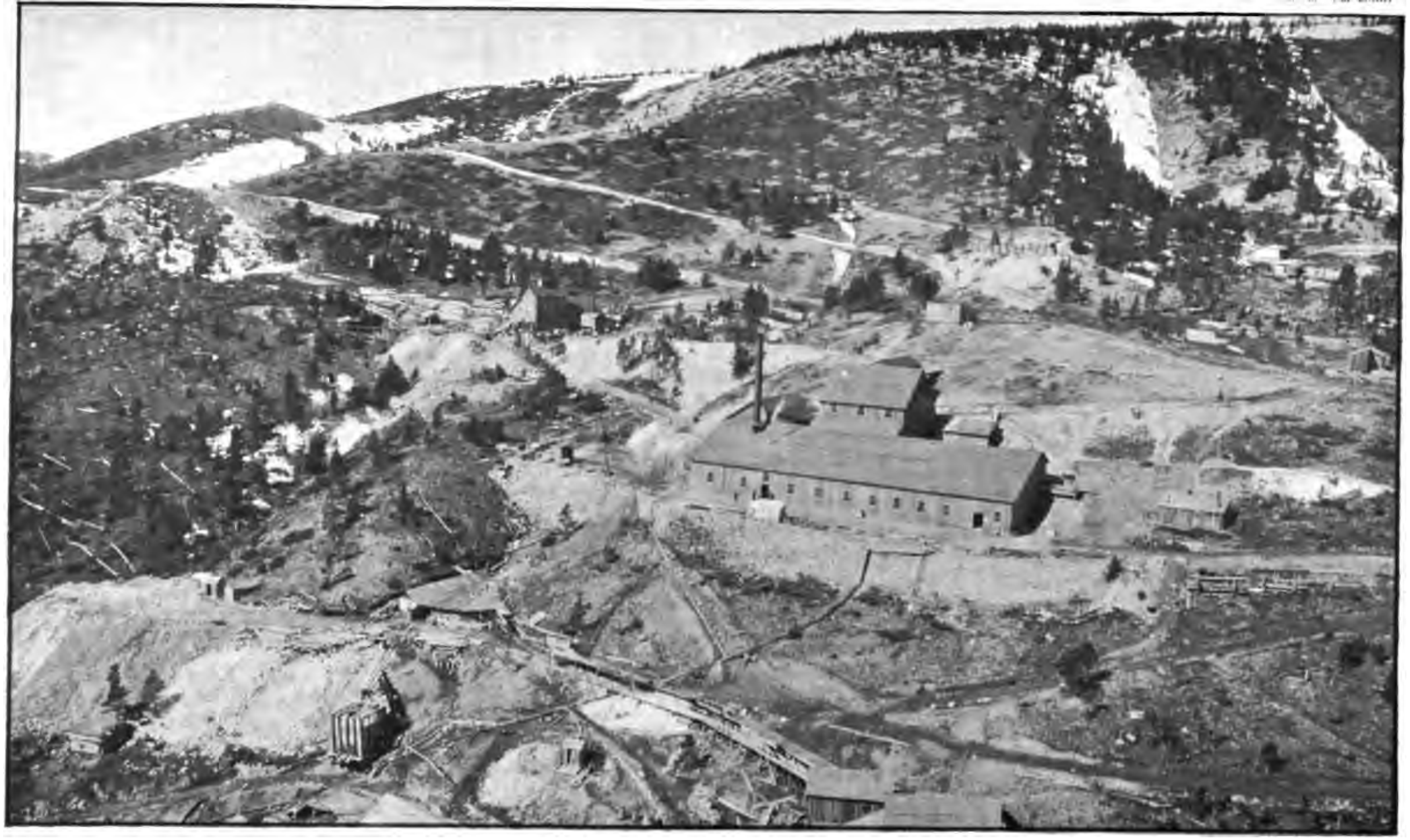


FIG. 54b.—Spotted Horse mine; vertical section through shaft and workings, October, 1889.



SPOTTED HORSE MINE.

of quartz and alkali feldspar in extremely minute, microscopic grains. In the process of alteration this character has been much changed, and the feldspars are largely converted into masses consisting of fibers and scales of sericite, a variety of muscovite. Originally also a ferromagnesian mineral, probably pyroxene, was present, and this has been leached out and replaced by masses of calcite, often retaining the shape of the original crystal; this occurs also at times in the altered feldspars. Scattered through this are many small masses and distinct crystals of pyrite which occur embedded sometimes in the calcite, sometimes in the altered feldspar, and sometimes in the groundmass. Where the surface of the pyrite has been ground off in the process of making the section there is often seen by reflected light minute dark spots, which may be due to some mineral embedded in it, but they are so small that their exact character can not be determined. The alteration of the porphyry is clearly that produced by the action of hot, solvent solutions, which have altered the original minerals and deposited the calcite and probably the pyrite.

The Spotted Horse mine is now owned by Mr. John L. Bright, of Columbus, Ohio, and Albert L. Losinger, of Maiden, Montana, the former owning a three-fourths interest. It is understood that a stock company will shortly be formed to operate the property. The mine was bonded for $30,000. The work done under the new ownership consists chiefly in the working out of the ore body exposed at the time of purchase and in the opening of the adjoining claim, the Kentucky Favorite, by means of a drift from the Spotted Horse shaft, run in a northwesterly direction. This drift starts from the second level at a depth of about 125 feet. The present owners have discovered several shoots of ore on the second and third levels, situated in close proximity to the 80-foot stope. The ore in these shoots was exceptionally high grade and consisted principally of tellurides; it was shipped to the Montana Smelting and Refining Company of Great Falls. The amount extracted did not exceed 100 tons, but the high value made it an extremely desirable ore to handle. The mill was closed down in April, awaiting a supply of coal from the neighboring mines. Previous to that the mill was running on an ore averaging $17 per ton, taken partly from the mine and partly from the surface working known as the "Open Cut," situated in the southeastern corner of the Spotted Horse claim, where the ore body has yielded some $35,000 from a space about 7 feet wide and 15 feet long. This bonanza was worked out under the former management, but considerable low-grade ore has been extracted by the present management from the vicinity of this ore shoot.

The pans of the mill have been replaced by copper plates, which were found to do quite as good work as that accomplished by the pans.

The old tailings are now being worked in a small cyanide mill with a capacity of about 40 tons per day, an extraction of 95 per cent (an average of $11 per ton) being made, a total amount of about 2,500 tons of tailings being available for work. The mine shaft will be sunk deeper by the present owners during the coming year.

The ore is treated in a 20-stamp mill, in which the free gold is extracted. The base minerals of the ore, said to be largely sulphides with telluride of gold, were concentrated and shipped for smelting. A letter from Mr. P. W. McAdow states that under his ownership about 65 per cent of the ore was free milling and 35 per cent telluride. The vanner saved 15 per cent of the tellurides, and 20 per cent was lost in the tailings and was carried down Maiden Creek.

The mine is not a wet one, barely enough water being obtained to supply the boilers of the hoist. For milling it has been found necessary to pump water from the head of Collar Creek Canyon, a lift of 300 feet and a distance of 2 miles.

The mill and hoisting plant were in poor condition in 1896, the mine and mill both requiring a considerable investment for satisfactory working.

FLORENCE MINE.

This mine was located by John Kemper in 1881. It consists of a tunnel cut in the limestone of Crystal Peak. The mine was worked only a short time, a number of years ago. At that time about 25 tons of very rich silver ore were shipped, of which 17 tons gave $9,000. The mine has not been worked to any extent since.

The Florence mine is situated in the limestone east of the porphyry mass, and the ore body occurs along the contact of limestone and a lesser porphyry intrusion. The ore appears to be mainly dog-tooth spar (calcite), stained and colored by copper carbonates, with green pyroxene characteristic of altered metamorphosed limestones, due to the proximity of eruptive rocks.

PILGRIM MINE.

This is a small working on the side of the mountain below the Florence. It consists of a thin seam of very rich silver ore, but the lead was too narrow and the limestone too hard for profitable working.

BUTCHER KNIFE MINE.

In Alpine Gulch this is the only prospect being actively pushed at the present time. An intrusive sheet lies in the calcareous Cambrian shales, and both are cut by a feldspar porphyry dike. The ore is along the contact between the porphyry and the limy, altered shale. A shaft 60 feet deep on the hill heads to a tunnel 180 feet long, driven to meet it. Some of the ore pans free gold; no general assay has yet been made and no ore has been shipped. Three or four men are employed in the mine.

Below the mouth of Alpine Creek, J. Wocasek has shipped small amounts of rich silver ore obtained from an open pit in the limestones.

NEW YEARS MINE.

New Years Gulch is the general name applied to the amphitheater cut in the mountains by the headwater branches of New Years Creek. A number of claims have been located here on contacts between the porphyry sheets and limestones.

The New Years mine is the only one from which ore has been extracted. It is still the property of the locators, Messrs. Harmon and Norman. The ore body lies on the under contact of an intruded sheet of porphyry, like the ore body of the Giltedge mines. The ore is a brecciated limestone, fissured and seamed with calcite seams and crusted with calcite, and decomposed porphyry also occurs in the ore body. Fluorite occurs here, replacing limestone fragments, as at the Spotted Horse mine. The ore is said to average about $14 a ton. An attempt was made to work the ore in a small cyanide mill, but the machinery was inadequate for the work and did not crush the ore fine enough to permit the extraction of the gold. As a seam of good coal outcrops at the mill, cheap fuel is assured.

BOULDER MINE.

This claim is on the northwest side of Pyramid Peak and consists of a tunnel 300 feet long driven in through the limestones toward the porphyry. The black Silurian limestone, which appears mineralized, is stated to be the ore and is said by the locator and owner, Mr. W. Wilson, to run 100 ounces in silver.

THE GILTEDGE MINES.

Ownership.—The Giltedge mines consist of a group of claims, of which Giltedge is but one, located in 1884–85 by Messrs. Wilson, Anderson, and Munson. The Giltedge claim was sold to Collins & Armington, who worked the property for a short while, building a small and crude cyanide mill for treating the ores. The ore body was worked without system, but sufficiently to show the existence of a large body of ore of low grade, easily handled and cheaply treated. The owners disposed of the property in 1893 to the Ammon-Stivers Mining Company, who employed Prof. W. B. Potter, of St. Louis, as consulting engineer. Under his guidance the mill was rebuilt and the plant greatly improved. His early treatment of the ore was not so satisfactory, however, as the method at present employed, and his plans for development were never carried out. The financial embarrassment of the company led to the attachment of the property, and in the summer of 1896 the property was being worked by the lien holders to satisfy unpaid wages of the miners and for the benefit of the lien holders themselves. The ore extracted during this arrangement was very successfully treated and considerable gold was shipped.

The property is at present (May, 1897) managed by a receiver, who is making many improvements in order to increase the output to 75 tons a day.

Occurrence of ore body.—The ore body occurs at the lower contact of an intrusive sheet of porphyry with the soft limestone overlying the massive, heavy-bedded Carboniferous limestones that form the mountain slopes. The structure here has been already described, and is illustrated in fig. 42 (p. 509). The beds are tilted, dipping at an angle of 30° away from the mountains, and, as the beds curve about the dome produced by the underlying laccolith, the limestone outcrops are not persistent in course, but curve about the mountains. The porphyry sheet is comformably intruded and then eroded, for the ore body at the contact is exposed on the surface of the mountain, and its upper portion has been swept away by erosion.

The ore is in part a crushed, broken, and altered limestone—much of it soft and clayey and some of it shaly—and in part a decomposed porphyry. The ore-bearing waters have dissolved out or altered the limestone and leached and decomposed the porphyry, but the impregnation with gold extends only a short distance, rarely over a foot, into the porphyry mass, the ore occurring chiefly in the limestone. A common feature of these deposits is that the mineral impregnation extends more or less uniformly and but a little way into the porphyry, and irregularly and much more deeply into the limestone.

The mines are on each side of a gulch cut deeply into the steep limestone slopes of the mountain, the openings being at an elevation of 6,000 feet, or 700 feet above the mill. The ore body is from a few feet to 40 feet in thickness. The porphyry sheet is about 50 feet thick, but was not measured. The limestone on the slopes above the ore body is indurated and splintery from the metamorphic action of the intruded sheet, and the fossils are replaced by fibrous, crystallized calcite, and their nature is not generally recognizable, although abundant crinoid stems, with Zaphrentis and spirifers, can be made out. The limestone underneath the porphyry is cracked, checked, and fissured, the seams carrying calcite. Even this dense and apparently unaltered limestone carries gold. The main mass of the ore body appears to be a shaly, argillaceous material, the result of the alteration of the massive limestone, and is itself generally rotted to clay. Fragments of this are seen inclosed in the porphyry, and it apparently represents a horizon of fissile rock through which the porphyry sheet has been intruded. This shale ore is not always present in following the lead, although it is quite common. Some 6 inches of the porphyry wall is ore bearing, and the barren-looking limestone itself often carries $6 in gold. The general appearance of the ore mass is, however, so unpromising that close assays of the face are necessary to avoid mining waste rock. But it is generally true that whenever the limestone is checked and fissured it carries gold. No other minerals save calcite were noticed, although on the surface exposures fluorite is abundant. The calcite forms stalactitic masses and incrustations, particularly in the old water-pipes and cavities which are occasionally encountered. In one instance a cavity was found which was gravel filled.

Underground workings.—The mine workings consist of an incline about 300 feet long, a lower tunnel, and a rock tunnel through the porphyry, together with a 60-foot winze and some meandering work which is apparently without any plan. There is a difference of over 500 feet in elevation between the mill and the mouth of the rock tunnel. This tunnel runs into the hill, the direction being N. 80° W. The walls exhibit a bleached, white, and decomposed porphyry, this rock showing sheeting or platy structure; the planes dip 25° to 30° toward the mouth of the tunnel, the seams being marked by a rusty color. The rocks at the ore bin are thin bedded and carry Carboniferous fossils. They strike N. 60° W. and dip 30° NE. The exposures along the ridge from the ore bins to the mill appear to be conformable, though the dip changes somewhat, becoming about 29° near the coal outcrop, where the strike is N. 30° W. The limestone slopes above the mine show three sheets of intruded porphyry, which are apparently conformable with the bedding of the limestones, and in the exposures seen are not over 5 feet thick. The workings are very advantageously situated for easy handling of the ore. At present there is a trestle and ore incline down to the bins from the mine incline. The situation of the mines and mill is admirably adapted to a gravity cable and ore-bucket arrangement to carry ore to the mill.

Character of ore.—The ore is low grade, and will perhaps average $10. The cost of mining is about $1, the hauling by teams to the mill is 50 cents, and the milling about $1.15 per ton. It shows no free gold, or, in fact, any visible mineral. The ore from the claims on either side of the gulch is very similar in character. The softer ore mined at the time of our visit consisted mainly of a clayey material, resulting from the thorough alteration of the original ore and containing masses of decomposed porphyry and irregular, rough-surfaced pieces of limestone up to a foot or two in diameter. These bowlders consist of crystalline and brecciated limestone, often surrounded by a concentric shell or crust of clay, resulting from the alteration of the bowlder itself. The softer clayey material also holds harder, cream-colored nucleal masses.

Treatment.—The cyanide process has been used with marked success at the Giltedge mill. In the earlier work the ore was heap-roasted and pulverized before treatment in the leaching tanks. The limy nature of the ore, resulting in much dust and in a slimy pulp through which the solutions percolated with difficulty and slowly, made this process unsatisfactory. Under the process as modified by the present owners, the ore as it comes from the mine is crushed and pulverized, and the treatment in the leaching tanks is very satisfactory, the leached pulp showing no gold upon assay. Following the practice elsewhere, it seems possible that the cost of treatment may be materially reduced if cheap copper sulphate can be supplied from local sources. The precipitate of cuprous aurocyanide is readily treated for the extraction of the gold.

The mill includes a small rock crusher, in which the ore is broken, and the product passes through a chilian mill, the pulverized material being lifted to be transmitted by cars to the leaching tanks or tubs. The resulting solution is precipitated at a lower level in the zinc room. The mill and offices lie on the flank of the hill formed of the coal-bearing rocks, which are mined for the use of the mill. (See Pl. LXXXVI.)

CONE BUTTE DISTRICT.

The Cone Butte mining district (unorganized) embraces the claims located in the northern half of the mountains, north of the fourth standard parallel of Montana as shown by the Land Office. This district includes a large number of located claims, none of which have as yet been extensively worked. The claims all show ore, rarely of high grade, and differing from that of the producing mines in character. The deposits mostly belong to the two classes already noted—first, deposits in fissures in porphyry; second, deposits on contacts of phonolite dikes.

The following notes show the extent of development of the various properties examined and the main facts of interest, the prospects being grouped by localities to facilitate reference.

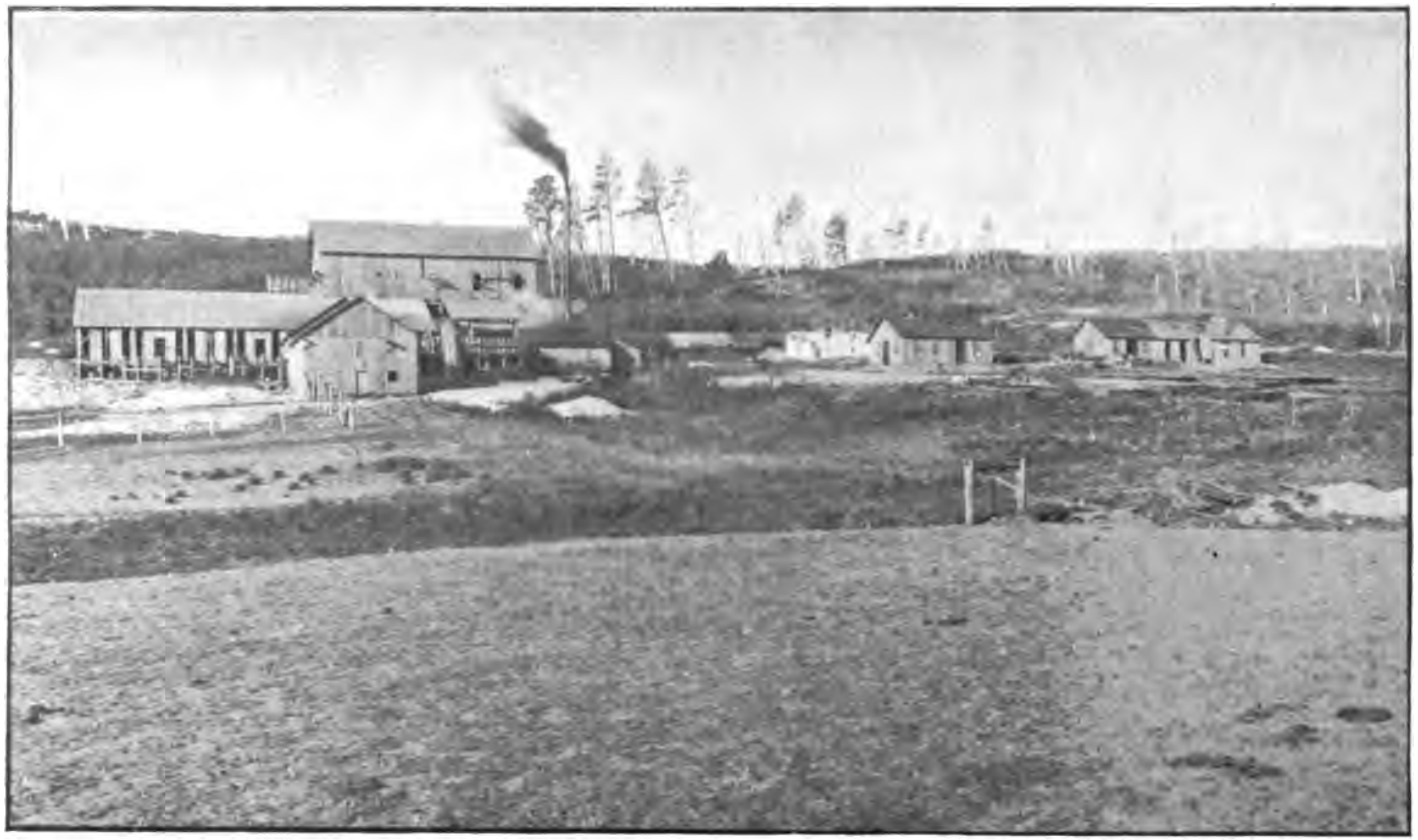
COLLAR GULCH.

The earliest developed mine in the district is located here—the Collar mine. It consists of a tunnel, stated to be about 1,000 feet long, penetrating the limestone of the Crystal Peak dome at the divide between Collar and Maiden creeks. What ore is now to be seen shows only a broken and silicified limestone, with apparently no considerable amount of ore-bearing constituent. It was worked as a silver ore. A large and expensive mill was built below in Collar Creek, which, however, was never practically used. The mine has been abandoned for many years and the machinery of the mill was largely used in the Spotted Horse mine.

The Ivanhoe is a prospect in these limestones, owned by Mr. L. Poland. The *Black Diamond* is a claim on a limonitic band in the limestones, owned by Mr. J. Dougherty and stated to carry $14 in gold. There are also several other prospects of a similar nature in limestone and not in porphyry.

WEST ARMELL CREEK.

Cave mine.—This was located early in the history of the camp by the Gies brothers. It consists of a chamber of silver-rich galena in



GILTEDGE MILL.

the limestone. The ore was hauled to a small smelter built for the purpose in Maiden, but after exhausting the pocket of ore in sight further work was abandoned.

First National.—This prospect was located by L. R. Davis on the contact of a rotted porphyry dike cutting ferruginous limestones. It affords a low-grade gold ore.

American Flag.—This prospect was formerly known as the Northern Pacific, and it belongs to Messrs. Anderson and Rhodes. Development consists of two shafts, the lower 50 feet, the upper 40; timbered. These are on a vein said to be 10 feet wide, of a dark-red to purple massive ore consisting of quartz and fluorite and showing occasional bunches of galena with rare grains of chalcopyrite. At the upper shaft the ore is much altered, and the porphyry of the vicinity is extremely altered, much leached, light colored, and rotten in character. It is stated that the ore is valued chiefly as a copper ore, that its average value is $15, and that 500 tons are on the dump. None has been shipped or worked.

Under the microscope, in thin section, this ore is seen to be composed of nearly equal parts of quartz in very fine grains and fluorite, the latter in larger masses of irregular shapes and also in fine grains penetrating the quartz. It has a deep blue-purple color, and, as usual with this mineral, the coloring pigment is very unequally distributed, being generally much deeper around the border of the masses, which have therefore a zonal, banded appearance. Besides these minerals an occasional speck of gray galena or lead ore is seen.

The development work upon this deposit of copper ores is not sufficient to warrant any further definite statement concerning its mode of occurrence or the future of the lead. The association of minerals is unusual, and, so far as we know, it is unknown elsewhere in the ore deposits of Montana.

In this connection attention should be called to the possible use of these copper ores in the cyanide treatment of the gold ores of the district. The lack of railroad communication and the present price of potassium cyanide and zinc make the cyanide process more costly than it would be if a cheap supply of copper sulphate or chloride were at hand, and this would give a local value to ores that would otherwise be of too low grade to work.

EAST ARMELL CREEK.

Voltaire.—This is the Hanson mine, at the extreme head of the creek. The "vein" consists of a decomposed phonolite dike cutting the Benton shales, which are here altered by the action of the various porphyry masses to black slates. The development consists of a tunnel on either side of the gulch, each driven in about 200 feet. The ore is a bluish, silicified porphyry, showing occasional pyrite. A small Huntington mill has been erected. The cyanide process was tried, but not successfully, probably owing in part to lack of experience. The ore carries gold and silver in small, thin streaks which run very high in value. The maximum value of ore treated was $30 a ton, but much of the ore did not average over $6 or $7. A little of the high-grade ore occurring in small pockets in the slate was shipped away. The mine employed nine men at one time, but was not successful, and is now closed down.

HEAD OF BOX ELDER CREEK.

Bob Ingersoll.—This claim, owned by Messrs. Anderson and Rhodes, is developed by a 30-foot shaft. The ore body occurs at the contact of limestone and porphyry.

Last Chance prospect, located by J. Murphy, is said to show a silver ore. The work consists of a timbered tunnel 75 feet long and a shaft 47 feet deep. The ore consists of a porous silicified limestone with green and blue specks of copper carbonates.

These two prospects are in the heavy limestones and porphyry sheets on the Elk Peak ridge.

Peerless, in Peerless Gulch, was located by Messrs. Shields and Noble. The ore body is a small, narrow vein running through the limestone near porphyry, and is developed by a timbered shaft of 30 feet and a tunnel of 30 feet. The ore carries copper, silver, and gold. Six tons of selected ore have been shipped, which gave an average of $100 per ton.

Birmingham, owned by J. Mitchell, is also located at this last locality. Development work consists of a tunnel, 75 to 100 feet long, run in on the contact of a mass of porphyry intruded in the limestone. The ore is a silver-rich galena and some of it has been shipped away.

Homestake, a claim of J. Leonard, consists of a 75-foot tunnel driven in on the contact of an intrusive sheet in the limestone. It shows lead ore, said to carry gold and silver.

None of these claims are being developed at the present time beyond the necessary assessment work.

CONE BUTTE MOUNTAINS.

Several prospects have been opened here, generally located on altered dikes of phonolite (tinguaite) cutting the main porphyry. The only one of these that deserves special mention is the *Golden Jack*. This is situated on one of the head forks of Edwards Creek, and the so-called vein is a dike of altered phonolite-porphyry cutting the main porphyry at its contact with altered beds of what are believed to be Jurassic shales. The development work consists of two tunnels 150 and 100 feet long, respectively, the latter being driven to secure drainage and crosscut the dike, the former being apparently exploratory and without definite purpose.

The porphyry in the unoxidized material of the ore body is cracked and somewhat silicified and shows on the cracked surfaces films of pyrite and patches of fluorite. This forms the ore, which is stated to run from $10 to $30 in gold. No average has been taken. Five men are employed in development work, but no ore had yet been shipped or treated from the prospect.

EAST FORK OF MAGINNIS CREEK.

A road has been built up this gulch which gives access to the Voltaire mine and other Hanson properties. There are a number of prospects in this gulch which are on contacts of the limestone of the Elk Peak dome with intruded masses of porphyry. Two locations have also been made on the contact of the Maginnis Peak syenite with the altered Cretaceous beds. The following claims may be briefly mentioned:

Gies mine.—On the contact of the porphyry and limestone are prospects owned by Mr. V. Gies. There is a tunnel 200 feet long, and gold ore has been mined which is said to have assayed as high as $80. About one ton of the ore has been shipped to Great Falls. Mr. T. Burke has a similar deposit, the ore from which is said to run about $20 in gold, and which has about the same amount of development. Similar prospects are claimed by Mr. C. F. Williams, and there are others of lesser note.

Other claims are located on the contact of intrusive rocks with the altered Cretaceous beds, among them the *Golden Eagle* claim of Mr. J. Murphy, which is partly in the igneous rock and partly in an altered conglomeratic material. Fissures in these, filled with films of pyrite, form the ore. No average value has been stated, but some of the ore is claimed to run very high. Work consists of a shaft and 170-foot tunnel. This claim is near the upper forks of the creek.

The other claim of this character is the *Edwards*, located below the last, and developed by a 70-foot tunnel driven into the black Benton shales, here converted into tough black slates by the action of the intruded syenite. The igneous rock crosses the creek at this point, and is seen on its east side. The ore is said to average $14 a ton.

WEST FORK OF MAGINNIS CREEK.

In the valley of this fork of the creek are several gold prospects, of the character of those previously described as occurring on porphyry dikes. The *Chicago* is one of these, occurring near the contact of the black slates with the main porphyry dike. It consists of a timbered shaft and tunnel. Similar claims are owned by C. Ridell and C. Stevens.

PLACERS.

The presence of gold in the porphyry is shown in the fact that wherever the streams have a course through porphyry areas, into which they are cutting, placer washings occur. A certain amount of placer work has been done, but the deposits are too small and the available water supply is too deficient to allow of work of any magnitude. It has been carried on mostly in Alpine Gulch, where a few men have made small sums from it. The gold found is usually very coarse and unworn, indicating its short transport.

IRON ORES.

On West Armell Creek, near its head, and not far from the contact of the porphyry with the west head branch, there is a considerable deposit of limonite. It lies exposed, forming a point between the main creek and a little side drainage. The latter has cut a small ravine down through it, and a thickness of at least 50 feet is seen in the banks. The material is of a spongy, fibrous, filamentous character, and altered stems and branches of trees are found in it. It appears to have been laid down by hot-spring action, the iron having been probably leached from the porphyry. As its boundaries merge back into soil and slide rock, the exact size of the deposit can not be told, but there are certainly several thousand tons in sight. The streams are wearing it away, and the water of West Armell Creek appears to be heavily charged with iron salts, which, as the stream loses its carbonic acid, are deposited as whitish to pale-brown carbonate in its bed.

A similar though much smaller deposit appears on the banks of upper Edwards Creek, while west Maginnis Creek, as previously noted, also deposits iron in its bed.

The Black Diamond lead, on the south side of the Crystal Peak dome, is also a bed of limonite, of what appears to be fair quality, lying in the limestones. It varies from 18 inches to 2 feet in thickness.

COAL.

Coal has been mined to a greater or less extent at the various localities marked on the map. The Cliff and Giltedge workings are the most developed.

Cliff mine.—The coal seam is opened in the narrow stream cutting of one of the headwater branches of Chippewa Creek. The mine is owned and worked by William Cliff, the product being marketed at Lewistown, Giltedge, and the Spotted Horse mine. The seam is here 2 feet 6 inches to 2 feet 8 inches thick. The coal comprises both bright and dull varieties, the former predominating; the two occur in irregular alternating layers, giving the coal a streaked appearance.

The shale over the coal is hard and firm and forms a good roof, needing little support. It is generally quite uniform, but in one place cuts out the coal, filling an old channel. An inch of coal occurs in the roof shale a few inches above the main seam. The coal is underlain by shaly sandstones, forming a gently rolling floor which occasionally rises and pinches the seam to 6 inches less in thickness. The seam, together with the inclosing rocks, dips at an angle of 14° to the east, away from the mountains.

A seam is worked by an entry 1,000 feet long, with the usual system of pillar and stall. The coal sells for $2.50 per ton at the mine, but when the seam is worked in benches and the lower 2 inches of blacksmith coal is separated, the latter sells for $14 per ton.

Lewistown coal mines.—There are coal mines about 4 miles south of Lewistown. From Lewistown to the coal mines the road follows the right-hand side of Big Spring Creek, along the borders of a very beautiful bottom land, well cultivated and cleared, and fringed with a thicket of haw bushes. Southward the inclosing slopes become steeper, in places forming bluff banks, in which the red clays observed on the first terrace above the town are seen to rest upon massively bedded but flaggy sandstone whose outcrop is marked by occasional pine trees. These sandstone beds form reefs separated by softer beds, and possess the peculiar yellowish, irregularly surfaced, knotty structure so well developed above the coal at Belt Creek, where similar sandstones also occur in the same red-clay series. The coal is first seen a mile or so below the forks of the valley on the south side of the creek. An abandoned opening is seen on the slope south of the stream, and another in a coulée just above the opening, being on the lower side of the coulée, while the mine now worked is half a mile up the side coulée on the west side of the creek. The mine belongs to Frank Bland, of Lewistown. The rocks strike diagonally across the creek and dip 5°, though the ledges slope down the creek at an angle of 2°. The coal sandstone is seen outcropping upon the right bank in occasional buttresses, while the overlying sandstones form continuous reefs which cross the road.

In the lower opening, which is now abandoned, the following section was made:

	Inches.
Dirty coal, under sand-rock roof	17
Light lavender-colored, clayey sandstone	24
Impure coal	16 to 18
Clay rock	
Lower seam of coal	

East of the crossing of Big Spring Creek, beyond the town, the bench land shows in a side hill, cutting the purplish-red and dark-red earths which characterize the rock series above the coal and prevail eastward to Boyd Creek.

The following section of the seam was made at the Bland workings:

	Inches.
Top coal	6
Massive slate	10 to 12
Bright coal	4
Rock parting, generally clayey, the lower 3 inches being at times a coal	6
Flinty clay parting, which is quite persistent	1
Cannel coal	8
Bright coal	4 to 5

The coal as sold is a splint, part of it a so-called "cannel" coal with

conchoidal fracture, while a part shows bright streakings, and might be classed as a semicannel.

Specimens from the different parts of the seam were collected and an analyses was made of each variety.

Table of analyses of coal from Judith Mountains.

[Analyses by J. Edward Whitfield, of Booth, Garret & Blair, for U. S. Geological Survey.]

Lewistown mines.	Moisture.	Vol. C.	Fixed C.	Ash.	Color.	Coke.
No. 1	6.66	44.78	38.67	9.89	Ash-brown	None.
No. 2	3.24	35.60	52.72	8.44	White	Worthless.
No. 3	2.44	37.01	49.41	11.14	White	Do.
No. 4	6.45	42.16	48.11	3.28	Brown	Do.

1. Coal from top seam, 6-inch band above slate.
2. Bright coal from middle layer of seam.
3. "Cannel" coal.
4. Bright coal from base of seam.

These analyses show that the coal is of excellent quality. The percentage of moisture is low, there being less than in the Lethbridge (Galt) coals, and but little more than in the Sand Coulée coals. The percentage of ash varies widely in the different layers, but the greatest is not high for a cannel, nor is it as great as that of other fields, while the average for the seam is relatively low. The fixed carbon percentage is the same as that of the best coals of the State.

Giltedge coal mines.—The coal seam near the Giltedge mill has a true southeast strike and dips 20° to the east. It rests on a bright, saffron-yellow rock, like that of Big Spring Creek, and is capped by a coarse-grained, gray sandstone. The seam is opened by an incline, which runs down a few feet and shows 2½ feet of dirty, dull coal, overlain by 4 feet of impure, argillaceous lignite shale. A persistent parting an inch in thickness was noticed 10 inches above the floor. Plant remains were collected here from the shales above the coal.

Warm Spring coal mines.—The coal is also opened in the Warm Spring anticline, where it is 14 inches to 2 feet thick, with 6 inches of bone in the center of the seam. There is a 120-foot drift, with rooms on each side. A little bright coal occurs in each bench.

Maiden Gulch.—At the mouth of Maiden Gulch on either side there are several coal prospects, but the beds are too much tilted and the coal is too much crushed to be successfully worked. Besides, the coal is shaly and full of pyrite.

New Years Gulch.—At the mouth of New Years Gulch the coal seam has also been opened in two or three places, the coal having been used here in running the engine of the New Years mill. The extent of the workings is inconsiderable, but the coal is of excellent quality; it is 29 to 31 inches thick, which is barely enough to warrant working. The bed dips at an angle of 35° to the north, away from the mountains.

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